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THE MOLECULAR CONSTITUTION OF STARCH AND THE MECHANISM OF ITS FORMATION

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STARCH forms the reserve carbohydrate material of most plants and is especially abundant in cereals, seeds, bulbs, and tubers. It exists in green leaves as a transitory product and is usually formed when soluble sugars produced through the photosynthetic activity accumulate in excess of the plant's need for energy production required in the metabolic processes. It is subject to rapid conversion into sugars by enzymes in the living cells, thus constituting an available reserve for the ready production of hexosephosphates needed for plant respiration. The amount of starch found in any tissue at any specific time is determined by the physiological activity of the plant tissue.

Starch falls into the group of carbohydrates known as polysaccharides. Two general conceptions have been prominent regarding the chemical constitution of this group. The earlier view of polysaccharide structure, held by Emil Fischer, was that the polysaccharide molecule is made up of a long chain of monosaccharide residues continuously liked by primary bonds. In this view the polysaccharide, like the di-, tri-, and tetrasaccharides, are produced by the union of n molecules of the monosaccharide, with the elimination of n-1 molecules of water, producing a formula of the type: $(C_6H_{10}O_5)_n \cdot H_2O$.

Another conception of polysaccharide structure, postulated by Karrer, Hess, Bergmann, Pringsheim, and others, which received much attention within the last two decades, is that the molecules are simple elementary units consisting of relatively few anhydrosaccharides (held by primary valences) of crystalloidal dimensions. The type of elementary unit suggested for starch ranged from a glucosan (anhydride of glucose) to an anhydride of a hexasaccharide. These elementary units were believed to possess the ability by means of residual secondary valences, to form large molecules of colloidal dimensions. This plan implies two states of aggregation, one structural unit within another, and may be represented by the formula $[(C_6H_{10}O_5)_m]_n$, where m represents the number of anhydromonosaccharide units in the elementary unit and n the number of elementary units, held by secondary valences to form a large micelle. At present, however, the second view known as the "association theory," is definitely being abandoned. Results of recent work on the structure of polysaccharides indicate that the molecules consist of chains in which the monosaccharide units are held only by primary valences. This view excludes the existence of two states of aggregation and the occurrence of secondary valences within the molecule.

The Haworth-Hirst model of the starch molecule

According to the view of Haworth, Hirst and collaborators (40, 48), the starch molecule is regarded as consisting of a chain structure made up of α-glucose units joined by glucosidic linkages

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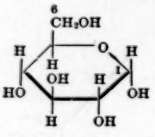
through the first carbon atom (reducing group) and the fourth carbon atom of the next glucose unit through the sharing of an oxygen atom (Fig. 3a). The glucose unit in the starch molecule possesses the normal glucopyranose form in which the first and fifth carbon atoms are joined through an oxygen atom to form an internal ring, as shown in the following perspective formula (Fig. 1):

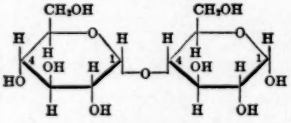


α-GLUCOPYRANOSE

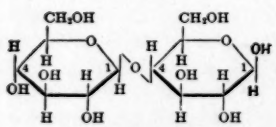
FIG. 1

The linkage between any pair of hexose units in starch is therefore the same as in the disaccharide, maltose (Fig. 2a).

In this connection it may be pointed out that polysaccharide cellulose also consists of glucopyranose residues (Fig. 3b); but, as in the disaccharide cellobiose, these monosaccharide residues are joined by β-glucosidic linkages between the first and fourth carbon atoms of the adjacent glucose units (Fig. 2b).



(a) α-MALTOSE

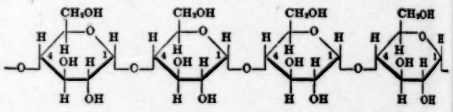


(b) β-CELLOBIOSE

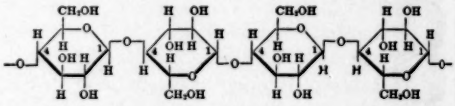
FIG. 2

The sole structural difference between maltose and cellobiose is a difference in configuration at the linkage between the glucose residues, similar to that which distinguishes the α- and β-sterioisomeric forms of methylglucosides; the maltose linkage is of the α-type, that of cellobiose of the β-type. This difference is shown in Fig. 2.

The degradation of starch with amylases produces a large quantity of maltose. The question has often arisen whether this disaccharide is preformed in the polysaccharide itself or produced by the enzyme as the result of reversion-synthesis from glucose. To provide evidence for or against this view, Haworth and Percival (41) degraded methylated starch under mild conditions with acetyl bromide in chloroform at 16°. These chemical reagents are known to have no synthetic action on glucose. They obtained a partly methylated maltose which on oxidation and further methylation produced octamethyl maltobionate, in 22.4 per cent yield. The production of a maltose derivative under these conditions definitely shows the maltose structure as a constituent part of the starch chain, which consists of recurrent α-glucopyranose units linked in positions 1 and 4.

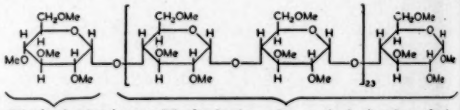


(a) α-LINKED GLUCOSE UNITS IN STARCH



(b) β-LINKED GLUCOSE UNITS IN CELLULOSE

FIG. 3



Hydrolysis gives 2,3,4,6-tetramethylglucose

Hydrolysis gives 2,3,4-trimethylglucose and one terminal MeOH

FIG. 4

When starch is methylated with methyl sulfate and sodium hydroxide, three free hydroxyl groups can be substituted in the starch molecule, producing trimethyl starch. On hydrolysis with acid of the methylated starch 2,3,6-trimethylglucose is obtained as the chief product, together with 4–5 per cent of 2,3,4,6-tetramethylglucose. Since the tetramethylglucose must be derived from the glucose that occurs at the end of the chain (see Fig. 4), the length of the chain may thus be calculated from the yield of the tetramethylglucose. It was found that the proportion of tetramethylgucose liberated is always the same (between 4 and 5 per cent) and is independent of the biological source of the starch (see Table 1).

This amount of tetramethylglucose corresponds to a terminated chain of 24 to 30 glucose units having a molecular weight of about 5000. The method of determining the chain length from the amount of tetramethylglucose obtained by hydrolyzing the fully methylated polysaccharide, is referred to as the "end group assay method" and has been applied to a number of polysaccharides, including starch, glycogen, cellulose, inulin, etc.

TABLE 1

Chain length of natural starches determined by the end group assay method

SOURCE OF STARCH	CHAIN LENGTH* IN GLUCOSE UNITS	INVESTIGATORS
Potato (amylose)...	24**	Hirst, Plant, and Wilkinson (52)
Potato (amylopectin).....	24	Hirst, Plant, and Wilkinson (52)
Potato.....	25	Baird, Haworth, and Hirst (1)
Waxy Maize.....	26–30	Haworth, Hirst, and Woolgar (46)
Canna.....	27	Hassid and Dore (34)
Wheat.....	24	Hirst and Young (50)
Horse-chestnut.....	28	Hirst and Young (50)
Rice.....	24–30	Hirst and Young (51)
Banana.....	24	Hawkins, Jones, and Young (39)
Maize (Golden Bantam).....	25	Hassid and McCready (35)

* It is now considered that the chain length determined by the end group method represents only a repeating unit in starch and not the whole molecule.

** It will be later pointed out that the amylose fraction differs from the amylopectin in that it is made up of long unbranched chains of about 300 glucose units.

Determination of molecular weights of various starches and their acetylated and methylated derivatives by physical methods such as by osmotic pressure, ultracentrifuge and viscosity measurements, however, showed the starch molecule to have a much greater molecular weight than 5000. Depending on the method of preparation of the acetylated and methylated derivatives, values ranging between 20,000 and 500,000 were obtained by different investigators for the molecular weight of starch. Haworth and Hirst (1, 40) therefore postulated that the end group assay method, showing a starch chain length of 24–30 glucose units, represented the chemical molecule in which the glucose units were united by primary valences (electron sharing bonds). These chemical molecules or simple macromolecules presumably were further associated by secondary valences to form large aggregate particles or micelles. These investigators held this view until about 1937.

The theory that the starch chains are held by secondary valences could not be substantiated by Staudinger and Husemann (90, 92, 93). They showed that the degree of polymerization of starch and glycogen could not be altered by conversion into their triacetates and the hydrolysis back to the carbohydrates. If, as postulated by Haworth and Hirst, these were micelles formed through aggregation of numerous short chain molecules (in the case of starch 24 to 30 and glycogen 12 or 18 glucose units) by van der Waal forces or secondary valences, their size should have been affected, because the forces holding the chains of the free polysaccharides together would be of a different magnitude than those combining the chains of the acetates. The stability and consequently the size of micelles formed from the chains of the polysaccharide after deacetylation must be different from those formed from their acetate chains. These authors, therefore, concluded that the colloidal micelles of starch and glycogen are macromolecules in which no secondary valences existed.

Bell (7), working with fish and rabbit glycogens, demonstrated that on hydrolysis of the fully methylated derivatives, followed by quantitative separation of cleavage products, 2,3,6-trimethylglucose (main product), 9 per cent of 2,3,4,6-tetramethylglucose (end group) and 15 per cent of dimethylglucose were obtained. This amount of "end group" (tetramethylglucose) corresponded to a chain length of 12 glucose units, which agreed with the chain length of rabbit glycogen previously reported by Haworth and Percival (42). Later, Haworth, Hirst, and Isherwood (44) also found among the hydrolysis products of fully methylated glycogen an amount of dimethylglucose about equivalent to that of the tetramethylglucose isolated as the "end group." The presence of considerable quantities of dimethylglucose was also observed in starch after Hirst and Young (49) improved the method of quantitative separation of hydrolysis products of starch. Small amounts of dimethylglucose were previously reported by

Haworth and Hirst in the hydrolysis products of methylated starch, but this was usually attributed to incomplete methylation.

It was difficult to reconcile the occurrence of dimethylglucose among the cleavage products of methylated starch and glycogen with the view that the molecules of starch and glycogen exist in the form of unbranched straight chains. The uniform 1,4 linkage of a continuous chain (in the case of starch 24–30 and glycogen 12 or 18 glucose units) should yield only trimethyl- and tetramethylglucose as the products of hydrolysis of methylated starch and glycogen. The fact that dimethylglucose is also present in considerable quantitaties indicates that some hydroxyl groups are occupied through linkage and therefore not subject to methylation. As an explanation of the occurrence of dimethylglucose, Haworth, Hirst, and Isherwood (44) suggested the possibility of "cross linkage" between individual chains, which

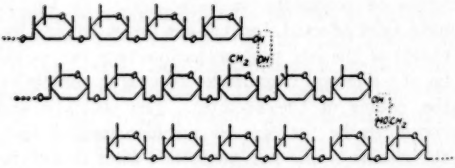


FIG. 5. HAWORTH AND HIRST'S STRUCTURAL FORMULA FOR STARCH OR GLYCOGEN

Each chain (repeating unit) contains 24–30 glucose residues in the case of starch, and 12 or 18 in the case of glycogen.
(From Bawn, Hirst, and Young (4).)

would also apply equally in the case of starch. This conception is expressed by a diagram in Fig. 5, showing the aldehydic glucose unit at the end of one chain linked with an hydroxyl group of a glucose unit in an adjacent chain. The assumption of such "cross linkages" would explain the presence of occasional glucose units with only two exposed hydroxyl groups, thus accounting for the dimethylglucose in the methylated starch and glycogen.

Haworth and Hirst's previous postulation based on a chain structure comprising the molecules of starch and glycogen would presume the existence of one free reducing glucose residue in every 24–30 glucose units (reducing end of the chain) in the former and one reducing residue in every 12-18 units in the latter. On this basis, the two polysaccharides should possess considerable reducing values, which, however, is not the case. The assumption of the existence of "cross linkages" between the chains explains the non-reducing properties of glycogen and starch.

It was demonstrated (21, 3) that the dimethylglucose derivative is the 2,3-dimethylglucose and comes directly from the methylated starch (22). Similarly the dimethylglucose obtained from glycogen appears to be also the 2,3-dimethylglucose (44), which shows that the position on the 6th carbon atom takes part in some linkage. Haworth and Hirst assume that this position is involved in "cross linkage" whereby individual chains are held together. Thus, the starch or glycogen chains are combined in such a way that the free reducing group of a glucose unit of one chain is glucosidically linked with the 6th hydroxyl group (primary alcohol group) of a glucose unit in an adjacent chain. These authors now believe that the link binding the repeating chains (units) in starch and glycogen is a normal covalent bond (primary valence) involving sharing electrons between nuclei, such as is found, for example, in disaccharides. When methylated starches or methylated inulin are treated under the same conditions with aqueous methyl alcohol, containing oxalic acid, the course of the disaggregation reaction, as indicated by viscosity and osmotic pressure measurements, is comparable for both. However the velocity of hydrolysis of the latter is about six times greater than the rate of disaggregation of methylated starch. Bawn, Hirst, and Young (4) conclude that, since the reaction velocity and disaggregation process of methylated starch are of the same order as those obtained on hydrolysis of compounds possessing glycosidic linkages, the repeating units of the starch molecule are therefore held by normal convalent bonds, intermediate in strength between that of a furanose linkage (as in sucrose) and a pyranose linkage (as in maltose).

Hirst and Young (51) showed that regardless of the method of preparation of the methyl derivative, whether the starch was methylated directly in the air or in nitrogen, or whether the methylated starch was prepared through the acetate and irrespective of the molecular weight of the methylated starch, the percentage of end group (tetramethylglucose) obtained on hydrolysis remained unchanged. In all cases of preparation care was taken by these workers so that the methods of purification and of fractionation were such that no small chain fragments were present. Contrary to the view of Richardson, Higginbotham, and Farrow (81), the observed proportion

of tetramethylglucose (end group) could, therefore, not be attributed to random hydrolysis of long unbranched chains of similarly united residues during the preparation of the methyl derivatives. If this were the case, the proportion of end group should increase as the molecular weight decreased, which, however, was not the case.

The conclusion was therefore drawn that the starch molecule is built up of a large number of chains (repeating units) joined together laterally, forming a branched structure. In support of this view, a viscous methyl starch containing about 80 repeating units (molecular weight approximately 500,000) was disaggregated with methyl alcohol containing oxalic acid into a non-viscous, homogeneous methyl derivative. Osmotic pressure and ultracentrifuge measurements showed that the latter had a molecular weight corresponding to about 3 repeating units (90 glucopyranose residues). On hydrolysis of this disaggregated methyl derivative, it gave the same amount of tetramethylglucose as the viscous derivatives. Further treatment with alcoholic oxalic acid of the methylated starch component, corresponding to 90 glucose residues, resulted in hydrolysis of the main chain. For this reason, Bawn, Hirst, and Young do not consider as conclusive the proof that the fundamental unit in starch exists as a repeating unit of 24 to 30 glucose residues. They state: "It is not possible from the evidence at present available to exclude the alternative view that the ultimate repeating structure has a molecular weight of 20,000 and contains three terminated chains not necessarily equal in length."

Although these authors conclude that the starch macromolecule is held together in soluble state only by primary valences, they do not exlude the possibility that the macromolecules themselves are associated by hydrogen bonds to form large particles. Starch always exists in plants in granular form. When heated with water the granules are disrupted, forming a paste, which can be reprecipitated either by treatment with alcohol or by allowing the paste to stand for several weeks. It is noted that the starch granule is disrupted by solvents such as water and acids, agents known to affect hydrogen bond formation. They are, therefore, of the opinion that the intramolecular forces involved in granule formation are most likely the hydrogen bonds.

Staudinger's view on the structure of starch

Staudinger and Husemann (90,91,92) claim that starch, like glycogen and cellulose, is a very large macromolecule and consists of more than

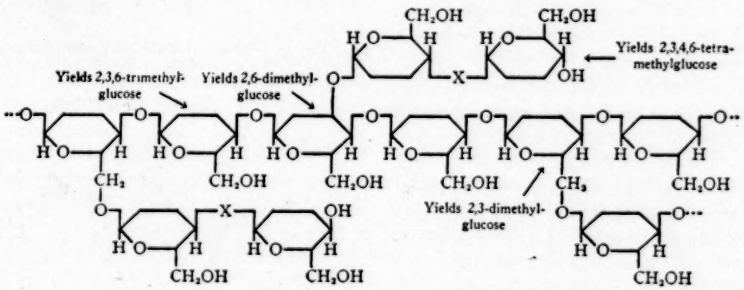


FIG. 6. STAUDINGER'S STRUCTURAL FORMULA FOR STARCH
(X = 20 glucose units)

1000 glucose residues united through primary valences. Their conclusions are based on viscosimetric and osmotic pressure measurements. In formulating the conception of the structure of starch these authors attempt to reconcile their views with those of Haworth. This structure is represented by Fig. 6. They picture a long central chain of glucose units linked through the hydroxyls of the first and fourth carbon atoms. The free hydroxyls, alternately on the third and sixth carbon atoms, of every second and fourth glucose unit in the chain are in turn involved in glucosidal linkage with similar shorter side chains of about 20 glucose units in length. The free-non-reducing terminal glucose residues of these short chains are responsible for the tetramethylglucose obtained on hydrolysis of methylated starch. According to the interpretation of these authors, the amount of this tetramethylglucose constitutes

the "end group" which Haworth and Hirst use to calculate the length of the chain. Thus, a starch molecule built up in this way from a main chain with a number of shorter side chains will build a macromolecule of more than 1000 glucose units.

Freudenberg's conception of starch structure

Schardinger (86) has shown that when starch solutions are exposed to the action of the microorganism *Aerobacillus macerans* a mixture of water-soluble dextrins are produced from which two distinct, non-reducing crystalline compounds may be readily isolated, α and β dextrins (Schardinger dextrins). The constitution of these dextrins was determined by Freudenberg and Meyer-Delius (23). They showed that the α-dextrin consists of five anhydroglucose units (pentaglucosan) joined by α-glucosidic linkages, forming a ring. The β-dextrin has a similar structure, but consists of six anhydroglucose units (hexaglucosan). The yield of the crystalline dextrins in some cases amounts to about 40 per cent of the original starch. On hydrolysis of the methylated Schardinger dextrins 2,3,6-trimethylglucose is obtained as the sole product.

It is difficult to reconcile the existence of such closed rings in the starch molecule with the present views on starch structure which regard the molecule as consisting of open branched chains, abundant evidence of which is now available. The question whether the crystalline dextrins are preformed in starch or formed as the result of synthetic activity of the living organism is, therefore, important. The fact that the enzyme from *Bacillus macerans* forms Schardinger dextrins from starch, after all the microorganisms have been filtered out, led Tilden and Hudson (97) to assume that the crystalline dextrins are preformed in starch and are components of the starch structure. It should, however, be pointed out that synthesis as well as degradation of polysaccharides may occur as a result of enzyme action. For example, the same enzyme, muscle phosphorylase, which in the presence of inorganic phosphate converts glycogen to glucose-1-phosphate (Cori ester) *in vitro*, will synthesize starch from the same ester (6).

Freudenberg (24) bases his conception of starch structure on the screwlike model proposed by Hanes (28), shown in Fig. 7. The assumption of such a model would explain the formation of closed ring, non-reducing Schardinger's dextrins from starch, as well as the hydrolysis by α-amylase. Freudenberg postulates that the *Aerobacillus macerans* splits the starch to 5 or 6 glucose residues and, because of the screwlike arrangement of the original spiral, every first and fifth or sixth glucose unit of these fragments, being in such close proximity, are able to unite and form rings of 5 or 6 glucose units. Thus, according to this author, the Schardinger dextrins are not preformed in the starch molecule, but are formed from the winding spiral of the starch chain in the process of enzymic hydrolysis.

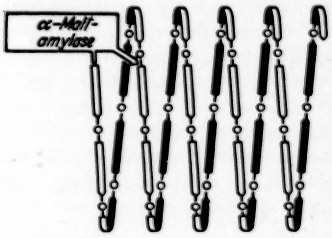


FIG. 7. HANES' HYPOTHETICAL STARCH MODEL, SHOWING THE POSSIBLE MANNER IN WHICH IT IS ATTACKED BY α-MALT-AMYLASE.
(From Hanes (28))

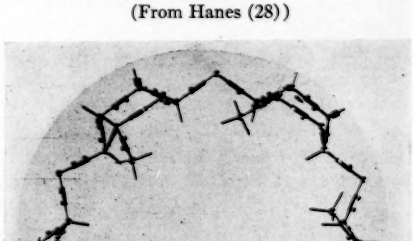


FIG. 8. FREUDENBERG'S α-DEXTRIN MODEL (SCHARDINGER'S DEXTRIN), ILLUSTRATING HOW FIVE GLUCOSE UNITS ARE COMBINED TO FORM A CLOSED RING.
(From Freundenberg, Schaaf, Dumpert, and Ploetz (24))

To show that such a screwlike structure is possible from the standpoint of space configuration, Freudenberg built a model of α-dextrin and illustrated the position of its atoms in space. The glucose units in ring-shaped pentaglucosan are situated perpendicular to the plane of the ring, Fig. 8. A minimum of 5 glucose units are required to produce such a ring without tension. The figure is based upon a *cis* form and the carbon

atoms 1 and 4 lie in one plane of the equilateral pentagon. The other carbon atoms of the glucose unit lie in a second plane. The C-O bond connecting the glucose units lie in a straight line. Owing to the particular angle of the oxygen an equilateral pentagon is formed with five oxygen atoms of the 1,4 linkages situated in one plane. In β-dextrin, with six glucose units, the corner oxygen atoms lie in two planes. Recent X-ray data, presented by French and Rundle (20), however, show that the α-dextrin (cyclohexaamylose) contains six glucose residues, while the β-dextrin (cycloheptaamylose) contains seven glucose residues in the ring.

The starch model consisting of coiled dextrin structures of different sizes offers an explanation for the hydrolysis of starch by α-amylase (24) and also for the formation of non-reducing dextrins by the *Bacillus macerans*. According to Freudenberg, branching takes place at about every 20th glucose unit in the spiral through linkage of the 6th hydroxyl group of the glucose units in the spiral. That branching occurs through the primary alcohol group is shown by the fact that the 2,3-dimethylglucose obtained, together with 2,3,6-trimethylglucose and 2,3,4,6-tetramethylglucose, comes directly from the methylated starch (22). Thus, approximately every 20th glucose unit has, in addition to the adjacent unit attached at the 4th carbon atom, another attached at the 6th position. From consideration of rotational data it is concluded that this linkage is of the α-type. This agrees with the work of Myrbäck (77) who is of the opinion that there are a small number of α-1,6 glucosidic linkages in starch. That these polymeric bonds are of the α-glucosidic type is deomonstrated by Meyer and Bernfeld (69), inasmuch as they are hydrolyzed with α-glucosidase, but not with β-amylase. Hence, in addition to the maltose linkage, the 1,6-linkage, similar to that existing in the disaccharide gentiobiose, is also present in starch. The screw-shaped starch molecule is considered to form rods of 15 to 20 Å thick, which are radially arranged in the concentric layers of the starch grain (24).

Amylose, amylopectin and synthetic polysaccharides

It has long been recognized that starch can be separated into two fractions possessing different physical properties. These fractions were designated as amylose and amylopectin by Maquene and Roux (62), as β-amylose and α-amylose by Meyer (65). The former is easily soluble in water and forms a slightly viscous solution; the latter is more insoluble and gives relatively opalescent and highly viscous solutions. Various methods have been employed to isolate the two starch fractions. Gatin-Gruszewska (25) swelled the starch in 1.5 N sodium hydroxide; upon neutralization of the solution the amylopectin precipitated out. Ling and Nanji (59) separated the two fractions by freezing a starch paste and then thawing. Samec and Mayer (83) autoclaved starch paste and then electrodialyzed it. The amylopectin (erythroamylose) precipitated out, while the amylose (amyloamylose) remained in solution. However, no sharp separation could be effected between the two starch fractions, using these methods, and their proportion greatly varied depending on the method of separation used. Different workers reported the amylose fraction of starch to vary from 17 per cent to 60 per cent. It now appears that the fractions designated as amylose and amylopectin were by no means identical, and did not represent the same portions of starch.

When starch grains are swollen in water at 60° to 80°, they are not ruptured, but the crude amylose diffuses out and can be separated from the swollen grains by settling or centrifuging. Meyer *et al.* (68, 73) thus separated maize starch into two fractions and studied their behavior toward aqueous chloral hydrate and the degree of hydrolysis with β-amylase (obtained from ungerminated barley). Their data indicate that maize starch is composed of two carbohydrates, possessing a different molecular structure: amylose (10–20 per cent), a mixture of polymers with unbranched chains and having a molecular weight of 10,000 to 60,000; and amylopectin (80–90 per cent) with greatly branched molecules, having a molecular weight of 50,000 to 1,000,000.

Since the amylose can be leached out from starch with water at 60° to 80°, its solubility in the starch granule is apparently greater than that of amylopectin. However, the amylose becomes more insoluble than the latter after it has been precipitated and dried. The small amount that dissolves rapidly retrogrades from solution. It appears that the more completely the amylose is separated from the amylopectin, the more insoluble the amylose becomes.

Meyer and Bernfeld (68) showed that the amylose, similar to the amyloamylose fraction isolated by Samec (85) from potato starch by autoclaving and electrodialysis, is completely

hydrolyzed with β-amylase to maltose. With unfractionated starch the enzymic hydrolysis ceases when approximately 60 per cent has been converted into maltose. The amylose also gives a brilliant blue color when treated with iodine. It was demonstrated by McCready and Hassid (63) that this amylose exists in potato starch to the extent of about 20 per cent and that its blue color produced with iodine is approximately six times as intense as that of amylopectin, and three times as intense as the color given by unfractionated starch. Its solubility in water is about 0.05 per cent. The amylose dissolves in warm 3 per cent sodium hydroxide, but retrogrades again when the solution is made neutral.

Bates, French and Rundle (99) have recently reported (after the present paper went to press) a method for the quantitative estimation of amylose and amylopectin of various starches, based on the difference in the ability of the two fractions to bind iodine in complex formation. Solutions of amylose and amylopectin were titrated potentiometrically with iodine, and the iodine bound by complex formation was determined. The activity of iodine in an amylose solution remains essentially constant upon addition of iodine until complex formation is complete, whereas there is a continual rise in the iodine activity when iodine is added to an amylopectin solution. Starches containing both components show a break in the curve, potential *vs.* iodine added. The point of inflection in the curve is taken as a measure of the amylose fraction present in the starch. They found the amylose content of the various starches, determined by this method as follows: tapioca 17, rice 17, banana 20.5, corn 21, potato 22, popcorn 23, wheat 24, sago 27, lily bulb, 34. It is of interest to note that waxy rice, waxy sorghum, waxy corn, and waxy barley starch are entirely devoid of amylose. Synthetic starch prepared by the action of potato phosphorylase on glucose-1-phosphate, in agreement with methylation studies, appeared to be essentially amylose.

On methylation of amylose and separation of the methylated sugars after complete hydrolysis, Meyer *et al.* (74, 75) and Hess and Krajnc (47) obtained about 0.3 per cent of 2,3,4,6-tetramethylglucose. This amount of "end group" corresponds to an approximate chain length of 300 glucose units. Hydrolysis of methylated amylopectin produced approximately 4.0 per cent of tetramethylglucose, a value corresponding to a chain length of 27 glucose units. These data are interpreted by Meyer *et al.* to show that amylose possesses an unbranched structure, consisting of chains of about 300 glucopyranose residues, while the amylopectin has a ramified structure, the branches having a chain length of approximately 27 glucopyranose residues.

Synthetic starch, prepared by Hanes (30) through the action of potato phosphorylase on glucose-1-phosphate (Cori ester) is similar to amylose in being completely hydrolyzed with β-amylase to maltose. Furthermore, the synthetic starch closely resembles the amylose in solubility, tendency to retrograde from solution, and in its intensity of the blue color resulting from the addition of iodine. Hassid and McCready (35) and Haworth *et al.* (43) showed that the synthetic starch, similar to amylose, is made up of long chains of glucopyranose units with little or no branching. The polysaccharides obtained through the action of crystalline muscle phosphorylase on glucose-1-phosphate *in vitro* is also similar in its properties and molecular constitution to the amylose fraction from potato starch. As demonstrated by Hassid, Cori, and McCready (38), this synthetic muscle starch, unlike natural glycogen or starch, is also made up of unbranched chains of about 200 glucose units.

The vague relationship that hitherto existed between the two starch fractions, amylose and amylopectin, now becomes clarified. There is a definite correlation among certain of the properties of different starch-like polysaccharides and their molecular constitutions. Amylose from natural starch and the synthetic polysaccharides synthesized *in vitro* by the potato and muscle phosphorylases have the following properties in common: sparing solubility in water, intense color production with iodine, and complete hydrolysis with β-amylase to maltose; these properties are identified with an unbranched long chain structure. On the other hand, amylopectin and animal glycogen, which produce a comparatively less intense color with iodine and are more soluble in water and also incompletely hydrolyzed with β-amylase, are recognized to possess a branched and relatively short-chain structure. See Table 2.

By means of selective precipitation with butanol, Schoch (88) isolated a fraction in 22 per cent yield from either corn or potato starch in "unique spherocrystalline form." These crystals are considered by Schoch to be formed probably as a result of the formation of an addition compound with the butanol. No "end group" determination was made on this crystalline fraction.

Since this paper went to press, Kerr and Severson (100) have reported that, by applying Schoch's butanol precipitation method to a hot water extract of corn starch, they obtained a product in the form of single minute crystals, which they also consider to be amylose having an unbranched structure. The workers also reported the existence of a third starch component (γ-amylose) isolated as an insoluble precipitate resulting from the conversion of corn starch with β-amylase or with *macerans* amylase. Wilson, Schoch and Hudson (103), attribute this insoluble fraction to the presence of fatty material and incomplete dispersion of the starch. Defatted starch, properly dispersed before submitting to enzyme action, produces a negligible amount of such insoluble material.

Bear (5) reported that the butanol precipitated crystalline amylose, similar to the synthetic polysaccharides, gives a V-type X-ray pattern. Similar to potato amylose and the synthetic polysaccharides, it also has a high conversion limit (93 per cent) to maltose with β-amylase (57). This crystalline starch fraction must therefore be closely related to amylose and probably possesses an unbranched structure.

The difference in behavior of β-amylase towards amylose and amylopectin assumes a theoretical interest with regard to the molecular constitution of starch. According to Hanes (28) β-amylase, when acting upon starch having branched chains, attacks the non-reducing ends, splitting off successive terminal maltose fragments, until it encounters some modification in structure. Since it is known that side linkages occur in glycogen and starch on the 6th carbon atom of some of the glucose units in the chains (21, 3, 44), these linkages are probably responsible for stopping the hydrolysis. With amylose and the synthetic polysaccharides, having no branched structure and therefore no side linkages, the hydrolysis by β-amylase continues until the whole molecule is degraded. An hydrolysis limit of 54 per cent for potato amylopectin as obtained by Hassid and McCready (37), would correspond to a rupture of the chain at approximately the 13th to 15th glucose unit. Fig. 9 represents diagramatically the manner in which β-amylase attacks the two starch fractions.

TABLE 2

Degree of β-amylase hydrolysis of starch fractions and their blue color intensities with iodine

SAMPLE	SOLUBILITY IN WATER	β-AMYLASE HYDROLYSIS	I COLOR INTENSITY	TYPE OF STRUCTURE
		per cent		
Natural potato starch	Colloidal solution	64	100	Branched
Amylose	Insoluble	100	310	Non-branched
Amyloamylose (Samec and Meyer)	Insoluble	100	310	Non-branched
Amylopectin	Colloidal solution	54	50	Branched
Erythroamylose (Samec and Meyer)	Colloidal solution	54	50	Branched
Synthetic potato* starch	Insoluble	98	305	Non-branched
Synthetic muscle* starch	Insoluble	97	278	Non-branched

* The synthetic potato and muscle starches were prepared through the action of potato and muscle phosphorylase on glucose-1-phosphate.

Molecular weight of starch

The molecular weight of starches or their derivatives is usually determined by osmotic pressure, viscosity and ultracentrifuge measurements.

Samec (82, 84) using osmotic pressure measurements, obtained a molecular weight of 200,000 for amylose. Meyer, however, considers the value too high. He is of the opinion that Samec probably dealt with an aged amylose solution. Since it is known that amylose retrogrades readily from solution on standing, this fact might account for his high molecular weight of amylose. Osmotic pressure measurements of acetylated amylose in tetrachloroethane by Meyer *et al.* (72) gave a molecular weight of about 78,000 which corresponds to a molecular weight of 45,000 for the unacetylated amylose.

Carter and Record (12) obtained values for the molecular weight of starch, which has been partly degraded with hot alcoholic hydrochloric acid and then methylated, ranging from 40,000 to 124,000.

According to Staudinger the following empirical relation exists between the molecular weights of

certain polymers and the viscosity of their dilute solutions: specific viscosity, $\eta_{sp} = CK_mM$, where $\eta_{sp} = \eta_r - 1$, or the increase in viscosity produced in a solvent by dissolving a unit amount of substance in unit volume of the solvent; η_r = relative viscosity, or viscosity of solution divided by that of solvent; C = concentration, base moles/liter; K_m = a constant; M = molecular weight. "Base molecular weight" means the molecular weight of the occuring unit in the compound, such as 288 in triacetyl starch. The constant K_m is determined from some independent weight measurement, such as the osmotic pressure method. Staudinger determined K_m for both starch and glycogen to be 10^{-4}.

Meyer (66) finds that the Staudinger equation does not hold for a number of chain polymers. The specific viscosity gradually increases with the increase of molecular weight of the polymers. The molecular weight of a certain polymer can therefore be found from its viscosity by interpolation, only if the molecular weights and viscosities of several members of the same series are known. This method is applicable, however, in the case of unbranched polymers, such as amylose. Comparison of viscosities of amylopectin gives only a very rough estimate of the molecular weight.

Hirst and Young (51) point out that the Staudinger equation, in its simple form, does not hold for methylated starches, but a relationship may be established between the molecular weight, determined osmotically, and the specific viscosity for unit concentration (η_{sp}/C; where C is $gm/100$ cc.) when the equation is modified. This relationship is shown in the graph of Fig. 10. The osmotic pressure measurement values for polysaccharides are taken from the work of Carter and Record (12). The fact that the observed points lie regularly on the line drawn in the graph provides an empirical method for the calculation of molecular weights from viscosity data in this series. The viscosity-molecular weight relationship for methylated starches gives an approximately straight line for derivatives of molecular weights from 20,000 to 150,000. In this range the modified equation is $\eta_{sp} = K_m'CM + a$, where $K_m' = 1.3 \times 10^{-4}$.

Hirst and Young used this graph in order to obtain the molecular weight of methylated rice starch. Depending on the method of methylation, values from 95,000 to 670,000 were obtained. Certain of the higher values were found by extrapolation. However, in view of the empirical nature of the relationship that exists between the viscosity and molecular weight of starch, these authors are also of the opinion that molecular weight determinations obtained by viscosity measurements should not be regarded as absolute but only as approximate values. The molecular weight determination of starch by the ultracentrifuge method is probably most reliable. Unfortunately the apparatus is not available in many laboratories, and as a result few data are available on the molecular weight determination of polysaccharides by this method. Hirst and Young (51) report the molecular weight of a sample of fully methylated disaggregated starch, determined by

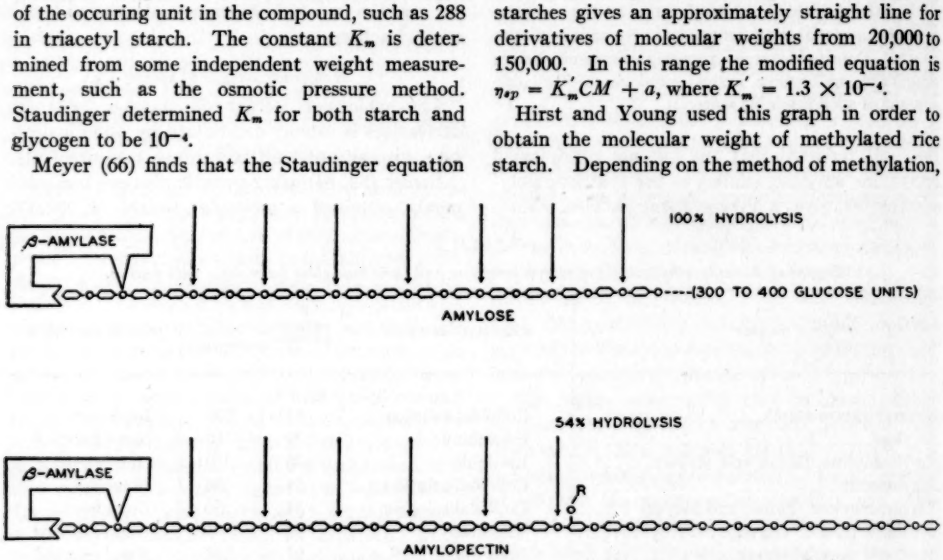


FIG. 9. SCHEME ILLUSTRATING THE MODE OF ACTION OF β-AMYLASE IN RELATION TO THE STRUCTURE OF AMYLOSE AND AMYLOPECTIN
(R = branched chain.) (From Hassid and McCready (37))
Molecular Weight (by osmotic pressure)

J. S. T. Philpot, as 20,000. This value agrees with those obtained by viscosity and osmotic pressure measurements.

Assuming that precise molecular weight determinations were possible, the values obtained for starch and starch derivatives could not be regarded as reflecting their true molecular weight. Starch, even when mildly treated, is subject to degradation. Certain linkages (possibly the weaker 1,6-glucosidic linkages which combine the individual chains, postulated by Bawn, Hirst, and Young) are easily ruptured. As pointed out by Mullen and Pacsu (76), any degree of hydrolysis, hardly detectable by chemical methods, considerably reduces the size of the molecule. For example, when a starch molecule consisting of 1000 glucosidic linkages is ruptured by some hydrolytic agent, resulting

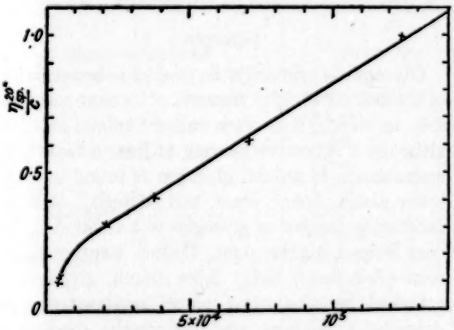


FIG. 10. VISCOSITY/MOLECULAR RELATIONSHIP FOR METHYLATED STARCHES
(From Hirst and Young (51))

in the formation of two molecules, each of 500 glucose units, it is actually only hydrolyzed to the extent of 0.1 per cent of the total linkages.

Non-carbohydrate substances in starch

Starch was often regarded to be associated in organic combination with fatty acids, silicic acid, and phosphorus. Except for the phosphorus it has now become evident that these exist in starch as impurities which can be eliminated by careful purification.

Taylor and Sherman (96) believed that fatty acids (palmitic, oleic, and linolic) are esterified with the alpha-amylose, contributing to the insolubility of this fraction. Schoch (87) recently showed that the fatty acids in corn, rice, and wheat starches can be removed without hydrolytic degradation by extraction with suitable hydrophilic fat solvents such as methanol or 80 per cent dioxane. Lehrman (58), in his study of the nature of the fatty acids associated with starch, arrived at a similar conclusion. Lipids must therefore be considered as natural impurities adsorbed by starch.

Posternak (80) isolated a glucose monophosphate by hydrolysis of potato-, sago-, or arrowroot starches, which was shown to be glucose-6-monophosphate. This author concluded that, whereas in the starches stored in tubers and rhizomes the phosphorus is combined in ester form with the starch, in the cereals the phosphorus is not directly linked to the starch but rather is present in the form of lecithins. Indeed, Schoch (87) has demonstrated that, while practically all of the phosphorus material can be extracted with hydrophilic fat solvents from corn, wheat, and rice as fatty acids, the same treatment removes only a very small fraction of the phosphorus in potato starch. Samec and also Meyer (67) consider the phosphorus to be present in the amylopectin, but not in the amylose fraction. Animal glycogen, when carefully prepared and purified is devoid of phosphorus (89). Ling and Nanji's (60) claim that starch contains silicic acid linked in the form of an ester cannot be substantiated.

Color reactions of starch with iodine

Freudenberg (24, 22) assumes that starch possess a hellical structure. When treated with iodine, the iodine molecules are deposited within the spirals, the spaces of which are of the exact size to allow the iodine to enter. The hydrogens of the 1st and 4th carbon atoms of each glucose unit form a hydrocarbon lining within the spiral, measuring about 5 Å across the unfilled open space. An iodine molecule, 6.3 Å long and 3.8 Å thick, can fit itself vertically within this spiral and appear on an average of one iodine to each sequence of 10 CH groups. The association formed between the iodine and the starch spirals affects its absorption bands, thus producing the color. In short chain dextrins of about six glucose units produced from starch by amylose degradation or treatment with acid, this arrangement of CH groups in the fragments is destroyed and therefore produces no color when treated with iodine.

Meyer and Bernfeld (70) object to this explanation on the grounds that some substances definitely known not to have a spiral arrangement, such as methylated cellulose, polyvinal alcohol, or cellulose which has been swollen with zinc chloride, also

give a blue color with iodine. The production of the blue color with iodine is not a property unique to starch. Certain colloidal suspensions and finely divided precipitates such as lanthanum subacetate, benzylidene phthalide and the methyl cyclo-acetals of acetol and acetoin also give colors with iodine similar to starch.

In a recent report Rundle *et al.* (101, 102) claim that, since no one model is capable of explaining the many known colored addition products other than starch, Meyer's objection to the helical starch model is not serious. These workers accept Freudenberg's starch model and present further evidence to strengthen this view by showing that starch-iodine solutions exhibit dichroism of flow; the light with its electric vector parallel to the flow lines is more strongly absorbed than light with its electric vector normal to the flow lines. The dichroism of flow requires that the long axes of the iodine molecules in the complex be parallel to the long axis of the starch-iodine complex. They believe that the optical properties of starch-iodine and starch-iodine fractions may be best interpreted in terms of helical starch chains.

Meyer and Bernfeld point out that none of these substances gives the color reaction with iodine in the state of either moecularly dispersed solutions or in crystalline state; the color occurs only in the case of colloidal precipitates having greatly distorted lattices. The iodine molecule is deposited in the fissures of these particles forming a complex which results in a change of the light absorption of the iodine, thus producing a color. Similarly, in the case of starch, the iodine is deposited in the super molecular aggregates or micelles producing the same effect.

Meyer and Bernfeld are of the opinion that several molecules of iodine unite with several molecules of starch to give the blue precipitate. The composition of the precipitate changes with the composition of the solution. An excess of iodine produces an iodine-starch complex of the approximate composition I_{2n} $(C_6H_{10}O_5)_{10n}$; when the amylose is in excess, its composition is approximately $I_{2n}(C_6H_{10}O_5)_{20n}$.

According to Meyer and Bernfeld, the intensity of the blue color with iodine bears a definite relationship to the crystallizing power of the polysaccharide. The unbranched amylose produces a brilliant blue color with iodine; the branched amylopectin gives a light violet color; the still more highly branched glycogen gives a red-brown color. It is observed that the tendency of crystallization is greatest in amylose and least in the amorphous glycogen. Molecules which have the ability to build crystallites associate in aqueous solutions to produce micelles and form blue compounds with iodine. The less the tendency of the polysaccharide to form micelles, the feebler is its reaction with iodine. A correlation can also be observed between the color intensity and the length of the unbranched part of the chains. The longer these chains are the more readily can crystallization and micelle formation occur. It is observed that the unbranched amylose, when converted by α-amylase or by acids into products of shorter chains, produce no longer an intensely blue, but a red color with iodine. This is explained by the fact that the short chains are not capable of forming well-arranged micelles.

Glycogen

Glycogen is primarily the reserve polysaccharide of the animal world. Because of its close relationship to starch, it is often called "animal starch", although a substance bearing at least a superficial resemblance to animal glycogen is found in some lower plants, fungi, yeast, and bacteria. A polysaccharide similar to glycogen was isolated in one case from a higher plant, Golden Bantam sweet corn (*Zea mays*) (35). Like starch, glycogen is attacked by the same plant amylases and is degraded to maltose, and, conversely, the animal enzymes, the glycogenolitic systems of the liver and muscle, will convert starch into glucose and lactic acid, respectively.

On hydrolysis of methylated glycogen 2,3,6-trimethylglucose is obtained as the main product, together with about 9 per cent of 2,3,4,6-tetramethylglucose and an equal amount of 2,3-dimethylglucose. In some cases, however, the amount of tetramethylglucose obtained from methylated rabbit glycogen was 7 per cent. Haworth, Hirst, and Isherwood (44) concluded that glycogen possesses a branched structure consisting of repeating chains of 12 or, in some cases, 18 glucopyranose units (see Table 3). Similar to starch, the glucose units in glycogen are united through α-1,4 glucosidic linkages. The attachment of the branches takes place through the 1,6 linkages. Its structure may be represented by the same formula as in the case of starch (Fig. 5).

Glycogen is soluble in water and, unlike starch, cannot be separated into two fractions, amylose

and amylopectin, which possess different physical properties and different structures. The molecular weight of glycogen determined by osmotic pressure measurements is in the region of 1,000,000 to 2,000,000 (12).

Willstätter and Rohdewald (98) demonstrated that glycogen exists in the liver in two states: (1) free, extractable with hot water (lyoglycogen) and (2) in combination with some protein which cannot be extracted with hot water (desmoglycogen). The "desmo" fraction can be liberated by various proteases, or after destruction of the protein material, with alkali. The glycogen then becomes soluble in water. These authors are of the opinion that the glycogen in the natural state is combined with some protein by a residual valence (secondary valence) to form what they call a "symplex". According to Meyer and Press (71), the glycogen-protein combination is resistant to β-amylase, but is attacked by it after the glycogen-protein has been precipitated with tungstic acid.

TABLE 3

Repeating chain length of natural glycogens, determined by the end group assay method

SOURCE OF GLYCOGEN	TISSUE	CHAIN LENGTH IN GLUCOSE UNITS	INVESTIGATORS
Rabbit	Liver	12	Haworth and Percival (42)
Rabbit	Liver	12	Bell (7)
Rabbit	Liver	18	Bell (8)
Rabbit	Liver	18	Haworth, Hirst, and Isherwood (44)
Fish (Gadidae)	Liver	12	Bell (7)
Horse	Muscle	12	Bell (10)
Mytilus edulis	Muscle	18	Bell (9)
Dog	Liver	12	Hassid and Chaikoff (33)
Snail (*Helix pomatia*)	Whole body	12	Baldwin and Bell (2)
Dogfish	Liver	12	Haworth, Hirst, and Smith (45)
Haddock	Liver	12	Haworth, Hirst, and Smith (45)
Hake	Liver	12	Haworth, Hirst, and Smith (45)
Dogfish	Muscle	12	Haworth, Hirst, and Smith (45)
Maise (Golden Bantam)	Seed	12	Hassid and McCready (35)

THE MECHANISM OF BREAKDOWN AND SYNTHESIS OF STARCH

Many carbohydrates of great importance, such as glucose or starch, cannot be produced in the laboratory and are synthesized only by plants. The problem of how the plants elaborate carbohydrates is of utmost interest. For more than half a century investigators attempted to gain an insight into the mechanism of carbohydrate formation in plants, devoting special attention to starch and sucrose formation, but only within the last few years has considerable progress been made.

Since the starch splitting amylases are known to occur in many different plant species, it was generally believed that the amylase system was responsible for conversion of the starch into sugar in the living plant. It was also often assumed that the same enzyme, under favorable conditions, played some rôle in reversing the process, polymerizing sugars into starch. A similar mechanism for glycogen breakdown and synthesis was assumed to take place in animal cells. The kinetics of hydrolysis of starch and glycogen with amylase were therefore intensively studied in the hope of elucidating the mechanism of breakdown and formation of these polysaccharides in the living cell. The fact that maltose and dextrins, the main products of amylase activity in the test tube, are not found in plant cells, necessitated the assumption that the kinetics of the amylase in the cell are of a different nature from those *in vitro*.

It was demonstrated only recently by Cori and Cori (16, 17) that not amylase, but an enzyme of an entirely different nature, is involved in the breakdown of glycogen (26). They have shown that animal tissues contain an enzyme, phosphorylase, which acts upon glycogen in the presence of inorganic posphate to produce glucose-1-phosphate (Cori ester). Soon after this discovery

Kiessling (56) and others (18, 14) found that when the same phosphorylases, isolated from yeast, muscle or liver, act on the glucose-1-phosphate, it is transformed reversibly into a polysaccharide. Hanes (29) subsequently demonstrated that higher plants, such as peas and potatoes, also contain phosphorylase which catalyzes the reversible reaction: starch + free phosphate ⇄ glucose-1-phosphate.

The formation of glucose-1-phosphate from starch and inorganic phosphate is considered to occur as the result of phosphorolytic cleavage of successive terminal glucose units from the chains of the starch molecule, the starch molecule being disrupted without water entering into the reaction. The reverse reaction, the formation of polysaccharide from the glucose-1-phosphate, is the result of successive "de-phosphorolytic" condensations. This process, whereby starch is broken down to glucose with the simultaneous entrance of inorganic phosphate at the maltosidic

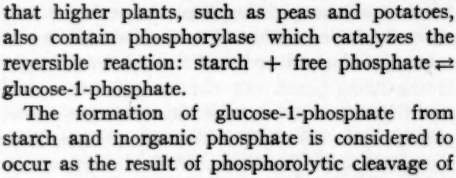


FIG. 11. PHOSPHOROLYSIS PROCESS, SHOWING THE ENTRANCE OF THE INORGANIC PHOSPHATE AT THE α-GLUCOSIDIC LINKAGES IN STARCH OR GLYCOGEN.
(From Cori, Colowick, and Cori (18a))

linkages, is described by Parnas (78) as "phosphorolysis" in contradistinction to hydrolysis where water is involved. Cori, Colowick, and Cori's (18a) diagram, Fig. 11, showing the entrance of the inorganic phosphate at the α-glucosidic linkages, resulting in the formation of the glucose-1-phosphate from glycogen, applies also to starch. Kalckar (55) pointed out that the equilibrium of this phosphorolysis reaction is "a clear illustration of thermodynamically spontaneous polymerization." The reaction which requires most energy is the phosphorylation of glucose to glucose-1-phosphate. When the latter is formed it is transformed into the polysaccharide practically without any expenditure of energy.

The reversibility of the starch-glucose-1-phosphate reaction is shown by the fact that the ratio of inorganic phosphate to ester reaches the same value in either direction. The reaction is represented as follows:

Starch + inorganic phosphate ⇄ glucose-1-phosphate
(inorganic phosphate) (ester-P)

Experiments with potato phosphorylase show that the equilibrium state of the reaction, defined by the values of the ratio inorganic phosphate/ester-P is not significantly affected by alterations within wide limits of the starch or the total phosphate (inorganic phosphate + ester-P) concentration. The position of the equilibrium is, however, markedly affected by a change in hydrogen ion concentration. Under conditions of greater acidity a larger proportion of starch and inorganic phosphate is formed. Thus, when the pH value was varied from 5.0 to 7.0, the values of the ratio inorganic phosphate/ester-P decreased progressively from about 10.8 to 3.1 (31).

A similar hydrogen ion concentration effect is found by Cori and Cori (18) in the case of glycogen and animal phosphorylase. The ratio of concentration of inorganic phosphate to glucose-1-phosphate, reached from either side, is 5.7 at pH 6.0 and 2.7 at pH 7.6.

According to Cori (15), when reactions occurring in the living cells are of such a nature as to lower the inorganic phosphate, the glycogen content will be increased. On the other hand, when the concentration of inorganic phosphate is increased, the glycogen will tend to break down; and if the glucose-1-phosphate is removed by other enzymes the breakdown of these polysaccharides will continue until the inorganic phosphate reaches a normal level. A similar dependence of phosphorylase activity on inorganic phosphate concentration, affecting the breakdown or synthesis of starch, may very well be expected to occur in plant cells.

In order to form starch from glucose-1-phosphate, the addition of small amounts of a suitable priming agent is required, such as starch, dextrin, or glycogen. Crude potato phosphorylase and glucose-1-phosphate prepared enzymically from starch, both usually contain sufficient dextrin impurities to catalyze the reaction. When purified potato phosphorylase and pure glucose-1-phosphate are used, the reaction will not proceed unless a small amount of priming agent (polysaccharide) is added. Lima bean phosphorylase, purified by the same method as the potato enzyme, does not, however, require the addition of a catalytic agent in order to produce starch from glucose-1-phosphate. Synthetic potato starch or synthetic muscle polysaccharide cannot serve as a priming agent (27).

The nature of the polysaccharide synthesized appears to be determined entirely by the particular kind of phosphorylase used and not by the nature of the activating polysaccharide. Thus, whether potato phosphorylase is primed with liver glycogen, plant starch or dextrin, the polysaccharide produced *in vitro* is always similar to the amylose fraction of potato starch (6, 38). On the other hand, when liver phosphorylase is primed with the same activating agents, a polysaccharide is synthesized, identical with animal glycogen (6).

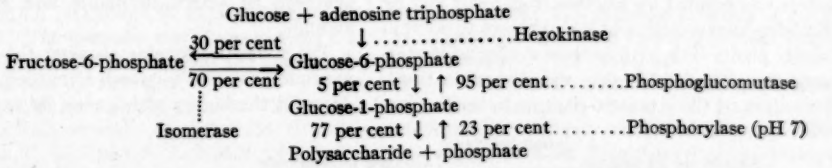
It should be pointed out that potato phosphorylase does not produce a typical plant starch *in vitro*. Neither does muscle phosphorylase synthesize a polysaccharide *in vitro* similar to animal glycogen produced *in vivo*. In both cases the polysaccharides synthesized *in vitro* are similar to the amylose fraction of potato starch (38). Liver and heart phosphorylase, however, synthesize a polysaccharide which is similar to animal glycogen (6). Nothing is yet known to explain the reason why these phosphorylases produce different polysaccharides *in vitro* from those in the living cells. It is possible that in the case of potato and muscle phosphorylase we are dealing with extracellular extracts in which the enzymic system involved is in some way modified.

Adenylic acid (adenine-ribose-5-phosphoric acid) is necessary both for synthesis of glycogen and formation of glucose-1-phosphate from glycogen, using purified phosphorylase from animal tissues. The adenylic acid apparently acts as coenzyme. No breakdown of glycogen occurs when it is removed by electrodialysis from the animal organ extracts. Addition of minute amounts of adenylic acid restores the phosphorylase activity of such extracts (14). The activity of potato phosphorylase, however, does not seem to be dependent on the presence of adenylic acid. The potato phosphorylase remains active even after prolonged dialysis of potato extracts. Green and Stumpf (27) are of the opinion that adenylic acid is not required in the breakdown or synthesis of starch. There is reason to believe that adenylic acid is a component of potato phosphorylase, but that the latter constitutes a firmly conjugated compound of specific protein and adenylic acid which cannot be resolved by dialysis. According to Cori, Colowick, and Cori (19), glucose-1-phosphate does not accumulate in the muscle extracts but is rapidly converted into glucose-6-phosphate by the enzyme phosphoglucomutase. Addition of a trace of Mg^{++}, Mn^{++}, and Co^{++} ions accelerate this transformation.

The reaction: glucose-1-phosphate $\rightleftarrows$ glucose-6-phosphate is shown to be reversible (94). At equilibrium approximately 5 per cent of the glucose monophosphate is present as 1-ester and 95 per cent as 6-ester.

Glucose in the presence of adenosin triphosphate (phosphate donor) is transformed by yeast hexokinase to glucose-6-phosphate. Thus, Colowick and Sutherland (13) were able to demonstrate the conversion of glucose into polysaccharide *in vitro* by making an enzyme system consisting of hexokinase, phosphoglucomutase and phosphorylase. Upon the addition of adenosinetriphosphate and glucose the latter was converted first to glucose-6-phosphate, then to glucose-1-phosphate and finally to polysaccharide.

The important achievement of polysaccharide synthesis by the aid of enzymes *in vitro* is presented by these authors in the following scheme:



Adenosine triphosphate indirectly supplies the energy needed for the synthesis of the polysaccharide from glucose. The energy required is necessary for the phosphorylation of glucose to glucose-6-phosphate. The transformation to glucose-1-phosphate and the subsequent polymerization to the polysaccharide proceeds with little change in free energy.

The over-all reaction involving the synthesis of the polysaccharide is written by Colowick and Sutherland as follows:

$$n \text{ adenosine triphosphate} + n \text{ glucose} \rightarrow \text{polysaccharide} + n \text{ adenosine diphosphate} + n \text{ phosphate}$$

where n is the number of glucose units in the polysaccharide molecule.

In the experiment conducted *in vitro*, the addition of large amounts of adenosine triphosphate is required for the synthesis of polysaccharide.

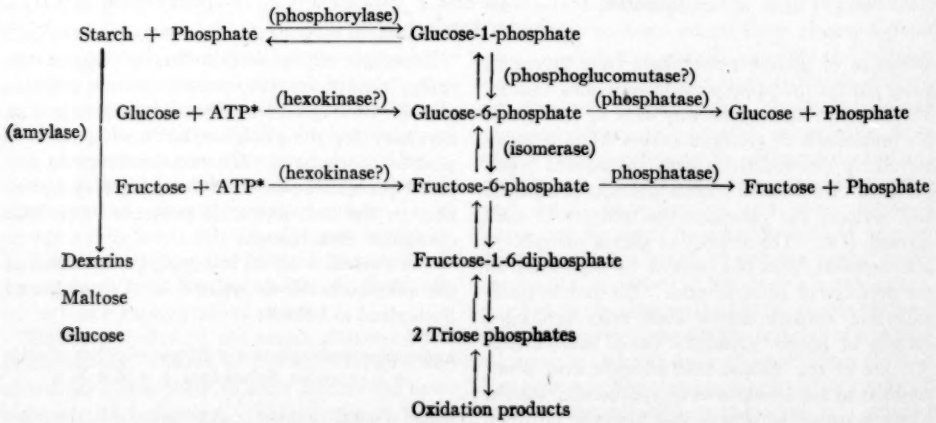
It is pointed out by these authors that synthesis of adenosine triphosphate in cell-free extracts of animal and plant tissues is "coupled" with the oxidation of a large variety of substrates. In a respiring system, very small amounts of adenosine triphosphate would be sufficient, since it is continuously being re-synthesized from adenosine diphosphate, or adenylic acid and inorganic phosphate. Oxidation reactions stimulate the production of starch or glycogen not only by causing resynthesis of adenosine triphosphate but also by lowering the concentration of inorganic phosphate, thus shifting the reaction in the direction of polysaccharide formation.

The glucose-1-phosphate does not accumulate in plant cells, but as in animal extracts, is rapidly converted into glucose-6- and fructose-6-phosphates. Hanes designated this system, consisting of two or more enzymes as "the phosphoglucose conversion system" (29). No detailed specific information concerning these enzymes in plants is available at present.

Extracts of muscle, brain, liver, and yeast also contain an enzyme, Lohmann's isomerase (61), which catalyzes the reaction: glucose-6-phosphate $\rightleftarrows$ fructose-6-phosphate. A mixture of the two esters was isolated by Robison from yeast and by Embden from muscle, and is also known to occur in higher plants (11). An enzyme similar to isomerase, capable of catalyzing the reversible transformation of the glucose-6-phosphate to the fructose-6-phosphate, was shown by Tanko (95) to exist in peas. When crude pea extracts are allowed to act upon starch in the presence of inorganic phosphate fructose-1-6-diphosphate (Harden-Young ester) is found. This indicates that an enzyme which transforms fructose-6-phosphate to fructose-1-6-diphosphate, similar to that found in yeast and animal tissues, also exists in the higher plants. When hexosediphosphate is added to barley sap, it is decomposed and forms pyruvic acid, showing that this ester is used in plant respiration (54).

No enzyme, similar to the hexokinase present in yeast, has as yet been found in higher plants. Neither has the enzymic system, responsible for the interconversion of the various hexosephosphates, been isolated and studied as has been done in the case of animal tissues. Nevertheless, by closely scrutinizing the brilliant researches of Cori and Cori, Meyerhof, Lohmann, Robison, Parnas, and others, the conclusion is inescapable that the mechanisms of starch synthesis and breakdown in higher plants, except for minor departures, is similar to that of glycogen in the animal tissues and yeast. The fact that practically an identical polysaccharide is produced, when either plant or muscle phosphorylase is allowed to act *in vitro* on glucose-1-phosphate (38), adds weight to the assumption that a similar enzymic system is involved in the synthesis of starch in plants and glycogen in animals.

The following scheme showing the relation of enzymic processes to starch formation and breakdown in the higher plants may be suggested:



*ATP = Adenosine triphosphate (Phosphate donor)

SCHEME SHOWING THE ENZYMIC PROCESSES OF STARCH SYNTHESIS AND BREAKDOWN

There is good reason to believe that glucose, formed as a product of photosynthesis, is phosphorylated by hexokinase, or a closely related enzyme, and forms glucose-6-phosphate, the latter being the first phosphorylated hexose in the scheme. The phosphate donor in this energy requiring reaction is probably adenosine triphosphate. Depending on the available carbohydrate supply in the plant, the glucose-6-phosphate may either be converted into fructose mono- and diphosphate and further oxidized in respiration or if the leaf is actively synthesizing and produces an abundance of glucose exceeding the amount required for respiration, the glucose-6-phosphate will be converted to glucose-1-phosphate and then polymerized to starch. Under adverse conditions of photosynthesis the tendency of starch is to break down through "phosphorolysis" to glucose-1-phosphate and then be converted to other hexosephosphates and respired. Thus, starch constitutes a readily available supply of hexosephosphates in the plant which may be drawn upon when needed for metabolic activities, the glucose-1-phosphate occupying the position of an important intermediary product. Starch may also be slowly hydrolyzed by amylase into dextrins, maltose, and glucose. This occurs especially under conditions of seed germination, when the amylase activity in the plant is high. Maltose and dextrins may then be present in the plants. Starch, however, cannot reversibly be synthesized by amylase from maltose or dextrins.

The formation of free sugars, abundant in the higher plants, can be explained as follows: Glucose may be considered a product directly formed in the process of photosynthesis; a rapid equilibrium is then established between this hexose and fructose through the mechanism of phosphorylation, as indicated in the scheme. On the other hand, reducing sugars may be formed as the result of phosphatase activity, by splitting off the phosphate from the hexosemonophosphates. Phosphatases capable of hydrolysing phosphoric acid esters, are widely distributed in higher plants (53, 79). Potato phosphatase is shown to readily split off the phosphate from the reducing monophosphates, but only to a very small extent from glucose-1-phosphate (64). Glucose—and fructose phosphate may also combine through the agency of some enzyme to form sucrose (32).

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THE BIOGEOCHEMISTRY OF ALUMINUM AND OF CERTAIN RELATED ELEMENTS (*Concluded*)

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THE COMPARATIVE BIOGEOCHEMISTRY OF THE LITHOPHIL ELEMENTS

THE preceding pages have summarized the available data on the biological occurrence and significance of a group of elements that appears to play at most but a minor rôle in the economy of living organisms. It is now appropriate to consider in a more general way the place of such elements in the biosphere, if only to indicate some of the reasons why the elements of group III appear to take no spectacular part in metabolism. In order to do this effectively a somewhat broader survey of the of the biological elements is necessary to provide a scheme, or a rough outline, of the specifications for a habitable planet, a statement of what is needed and where it is to be used in the construction of a biosphere, in which the flora and fauna of the earth may increase and multiply.

The scheme to be adopted is based primarily on the work of Goldschmidt (1934, 1937, 1938) though in part developed by other workers. The general conclusions are familiar to all geochemists, but some recapitulation is needed to provide a framework for the biological implications to be developed.

The cosmic abundance of the elements

The cosmic abundance of the elements, as ascertained from the study of meteorites and from spectrographic examination of the sun and other stars, is determined, as might be espected, primarily by the stability of the various atomic nuclei.

(1) In general the elements of low atomic number and mass are more abundant than those of high atomic number and mass.

(2) Apart from hydrogen, which is by far the most abundant substance in the universe, elements of odd atomic number are, wherever accurate comparison can be made, almost always rarer than their neighbors of even number (Oddo-Harkins rule).

(3) In both odd and even series there is a rise in abundance in the neighborhood of manganese and cobalt (odd number series), iron and nickel (even number series).

(4) There is a deep minimum towards the end of the curve corresponding to the short-lived radioactive elements. In the odd series, 85 and 87 are not known naturally, though artificial 85 has been studied not merely physicochemically but also physiologically.

(5) A deficiency of lithium, beryllium and boron is strongly marked in the cosmic curve. This is explicable by the fact that at temperatures of the order of 20,000,000°C, believed to exist in the interior of the sun and most other stars, there would be enough protons traveling with velocities sufficiently great to disintegrate the nuclei of these three elements. No cyclical regeneration of the kind supposed to occur in the cases of carbon, nitrogen, and oxygen is possible.

The above five features of the cosmic curve are in general in accord with what is known about the variation in stability of atomic nuclei of different masses. In the case of the short-lived radioactive elements, internal instability is manifest independent of temperature. In the case of lithium, beryllium, and boron, the conditions under which the elements can be destroyed are realized in the sun and whatever the origin of the solar system, it will hardly be doubted that terrestrial and meteoritic material has had a comparable thermal history. The differences in stability of the kind underlying the first three aspects of the distribution could only have had an opportunity to be effective at excessive temperatures under conditions quite unlike those directly observable today. There are, moreover, certain individual elements of odd atomic number, notably scandium, the

problematic elements 43 and 61, and rhenium, which appear to be abnormally rare. Gallium may perhaps have to be added to this list, though its rarity is largely relative to manganese, which is more abundant than would be implied by the general direction of the abundance curve.

The mean elementary composition of terrestrial living matter has been calculated approximately by Vinogradov (1935a). In general his data refer to the wet wood of forest trees, which form about 80 per cent of the living matter on land, but they are supplemented by a number of analyses of other organisms. For the major elements (H, O, C, N, K, S, P, Ca, Mg) the data are certainly satisfactory. For the minor constituents they are as certainly far less good. Much work has been done, both in Russia and elsewhere, since Vinogradov's summary. In presenting a new provisional curve, the quantities of lithium, boron, gallium, aluminum, titanium, vanadium, cobalt, and nickel have been revised to take into account all available information. The revised curve has been drawn semilogarithmically, against atomic number, but departs from that of Vinogradov in that the numbers of atoms have been related to 100 atoms of carbon. The data do not justify carrying the curve beyond element 31 (gallium), and within that range no quantitative determinations are available for beryllium, which is certainly very rare in organisms. The meagre information relating to chromium is discussed below. Scandium has been taken as comprising 5 per cent of the total rare-earth elements. The positions of the inert gases have been approximately indicated as if present in solution in water in equilibrium with air at S.T.P.

Vinogradov, who was much concerned with certain supposed regularities in the finer structure of his curve, was naturally well aware that its general form is similar to that obtained from similar plots of the elementary composition of other kinds of matter. It has, moreover, long been realized (Sestini 1885, Church 1888b, Fearon 1933) that the elements comprising the bodies of living organisms are predominantly the light elements. Both Lotka (1925) and Fearon have stressed the difference in the mean composition of the earth's crust and of living organisms. Though the commonness of the biological elements has often been emphasized, the most important element of all, namely carbon, on the properties of which life entirely depends, is not particularly abundant in the lithosphere and of but moderate abundance in the hydrosphere and atmosphere.

It will, however, be immediately clear, if the curves of Figure 6 be compared, that omitting from consideration the inert gases, which organisms cannot retain, the main biological elements are the *cosmically* common elements, particularly H, O, C, and N, and that the terrestrially abundant silicon and aluminum play a comparatively minor rôle.

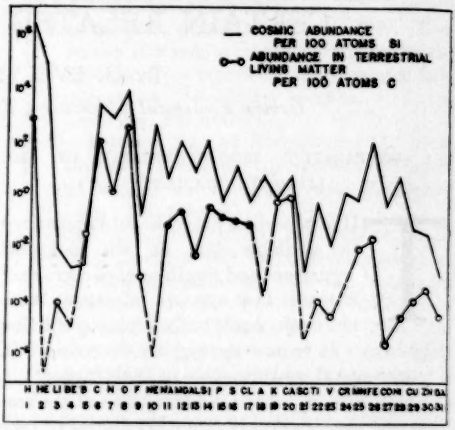
COSMIC ABUNDANCE PER 100 ATOMS Si
ABUNDANCE IN TERRESTRIAL LIVING MATTER PER 100 ATOMS C
H HE LI BE B C N O F NE NA MG AL SI P S CL A K CA SC TI V CR MN FE CO NI CU ZN GA
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

FIG. 6. COSMIC ABUNDANCE OF THE ELEMENTS RELATIVE TO 100 ATOMS OF SILICON, AND THE ABUNDANCE OF THE ELEMENTS IN TERRESTRIAL LIVING MATTER RELATIVE TO 100 ATOMS OF CARBON

TABLE 2

Order of abundance of atoms of commoner elements in cosmos, upper lithosphere, hydrosphere, atmosphere, and living matter

COSMOS	LITHOSPHERE	HYDROSPHERE	ATMOSPHERE	LIVING MATTER (TERRESTRIAL)
H	O	H	N	H
(He)	Si	O	O	O
O	Al	Cl	(A)	C
C	Na	Na	H (as water)	N
N	Ca	S	C	Ca
Si	Fe	Mg	—	K
Mg	Mg	Ca	—	Si
Fe	K	K	—	Mg
S	Ti	C	—	P

The thin zone constituting the biosphere, lying across the boundary of the lithosphere with the atmosphere and hydrosphere, is uniquely able to produce bodies in which the cosmic order of abundance of the four most abundant chemically active elements is reproduced. It is, however, clear that

the anomalously large quantity of superficial water on the earth as compared with Mars or Venus, and quite possibly the quantity of carbon also, give our planet a character that is exceedingly favorable for such superficial reassembling of material, in proportions more nearly resembling the general composition of the universe than are found in any other of the geospheres. The only element, other than inert gases, of atomic number less than 24, for which no biological function has ever been suggested in any organism, is beryllium, and this is the scarcest of the three light elements that are abnormally rare owing to thermonuclear reactions at high temperatures. Lithium is hardly more likely to have a biological function, though it is more widely distributed in organisms. Boron, which cosmochemically also belongs with these elements, forms a highly soluble anion and is accumulated in the hydrosphere; it is therefore reasonable to find that boron has acquired a function in plants. Fluorine, the cosmic abundance of which is in doubt, but which also may have been destroyed by thermonuclear reactions, seems to play a minor part in some skeletal structures. The biological availability of iron is primarily determined by its solubility at various pH and redox potential values. Yet it is possible that had iron not been a particularly abundant element, it would never have played the important part that we attribute to the element in the oxidative mechanisms of organisms. The great depression associated with the natural strongly radioactive elements is certainly reflected in biological material, though some radioactive elements, notably radium itself, are, for reasons that will be indicated below, undoubtedly somewhat commoner in organisms than would be expected from their cosmic abundance. Little trace of the Oddo-Harkins rule is exhibited by the elements of living matter, or for that matter in any terrestrial assemblage of materials. Only in the case of the rare-earth elements, which, migrating chemically as a more or less coherent unit, are apt to retain their initial proportions, do the even-number elements stand out as conspicuously more abundant, and even here we have already seen that in organisms, at least one exception of great interest may occur in the case of europium.

Examination of Fig. 6 suggests that insofar as cosmic abundance is involved in determining the quantity of living matter of observed composition on the surface of the earth, boron, potassium, phosphorus, and calcium are most likely to occur in limiting concentrations. Cases are known in which each of these elements does indeed act as a limiting factor though, in general, boron tends to concentrate in the hydrosphere, and the two metals are concentrated in the upper lithosphere by processes to be discussed in succeeding sections. The cosmic abundance of phosphorus, however, may well determine in part the biological productivity of the earth, particularly in view of the fact that the concentration of this element is reduced rather than increased in the accessible lithosphere, by the events to be considered in the next section.

Phase partitioning in the formation of the earth

The formation of the earth presumably resulted in the separation of liquid phases comparable in composition to the metallic, possibly to the troilite, and to the silicate phases of meteorites, and to a gaseous phase that may well have been almost entirely lost from the earth as it certainly would be from much smaller bodies.

The elements passing into the metallic phase are termed by Goldschmidt *siderophil*. Practically the entire terrestrial supply of the platinum metals, gold and germanium, have in this way presumably become inaccessible, being concentrated in the metallic core of the earth, along with a less disproportionate amount of certain other elements.

The elements passing into the silicate phase are termed *lithophil*, and include the alkalies, alkaline earths, aluminum, silicon, the rare earths, and a considerable part of the oxygen of the terrestrial globe.

The problem of a separate sulphide phase is difficult. Geophysical evidence is not in favor of its existence as an important discrete layer, and certain of the *chalcophil* elements appear to be commoner in terrestrial rocks than in the silicate phase of meteorites.

The *atmophil* elements include hydrogen, the inert gases, and to some extent nitrogen, carbon, phosphorus, the halogens, etc. They raise certain special, and largely unsolved, problems, which are of considerable biological interest.

An immense loss of both hydrogen and helium must have occurred early in the history of the earth. Without such a loss it is probable that photochemical reduction would have prevented the evolution of all but the simplest organic compounds (Wildt, 1937) and the development of the oxidation-reduction machinery of metabolism might well have been impossible even if complex organic compounds could have been found. The work of Rayleigh (1939) shows that the atmos-

pheric ratio of neon to argon was established prior to the solidification of the earth's crust. All elements present as gaseous molecules of molecular weight not exceeding 19 therefore should have suffered a great reduction in abundance. Although the formal dynamic treatment of atmospheric loss from a planet has been well developed, and at least a qualitative explanation of the continued escape of helium through collision with metastable oxygen atoms, is available to account for the low helium content of the atmosphere, in spite of the production of that gas by radioactive substances, the consistent explanation of the distribution of atmophil elements in the earth's atmosphere and crust still appears impossible. The data are not entirely satisfactory, but the known terrestrial quantities of carbon and nitrogen seem to suggest extensive loss of these elements. It must not be forgotten that although carbon dioxide is the sole atmospheric constituent known on Venus, the amount present above the reflecting layer is very small compared with the total amount, of the order of 10 atmospheres, that has passed through the biosphere in the course of geological time. There is no obvious way (Wildt, 1942) in which CO_2 could be fossilized on so dry a planet, and it is therefore not improbable that Venus is relatively deficient in available CO_2, though less so than in the case of water. A fuller understanding of the problem of the beginning of life on earth is dependent on a plausible reconstruction of the terrestrial atmosphere present after solidification of the crust. Some light might be thrown on the matter if more information were available as to the atmospheres of the terrestrial planets. Even though further studies of this kind might well prove fruitless, the importance to philosophical biology of any positive results is potentially so great that, in their prosecution, the use of the most powerful instruments would be justified.

It is impossible to say to what extent loss of the extreme siderophil elements has prejudiced the biochemical specialization of organisms. Neither the platinum metals nor gold appear to offer many possibilities. The occurrence of up to 1.6 per cent GeO_2 in certain coal ashes (Goldschmidt and Peters, 1933a) might suggest the conclusion that a specific accumulation of the superficially rare element germanium was included in the Carboniferous flora. Goldschmidt, (1931), however, considers that the concentration is due to the reduction of germanium compounds circulating in telluric waters. Of the other siderophil elements, calculations, based on Goldschmidt's figures for the concentrations in the metallic phase of meteorites and in the silicate phase both of meteorites and of the earth, show that if we assume a ratio of silicate to metallic phase of 65:35 for the earth (Russell, 1935), equalizing the concentrations in the two phases would increase the quantities in the lithosphere of nickel 9.4 times, of cobalt 5.65 times, of molybdenum and iron 3.33 times and of phosphorus 1.89 times. The biological availability of the first four elements is probably determined by their behavior in the fractional crystallization of the silicate phase and by solubility relations; the multiplication of the phosphorus content of the lithosphere by 1.89 might well lead to a general increase in the biological productivity of the earth. The loss of phosphorus to the metallic phase may be one of the factors ultimately restricting the development of life.

The converse process, the enrichment of the lithophil elements in the more superficial layers of the earth, is of less significance, owing to the high ratio of the mass of the silicate to that of the metallic phase. It is, moreover, clearly of quite subordinated importance compared to the distribution of the elements in the different solid fractions that crystallized from the liquid silicate phase.

The fractional crystallization of the silicate phase

The major constituents of the silicate phase of meteorites are oxygen, silicon, magnesium, and iron. The great mass of the lithosphere is composed of ferro-magnesian silicate rocks representing the supposed early products of crystallization. The details of the process of solidification are uncertain, but it is generally agreed that the more acidic rocks of the continental shields, which are principally aluminosilicates rich in alkalies and the heavier alkaline earths, and of lower density and lower melting point than the basic ferro-magnesian rocks, represent later products of crystallization than do the latter. The major factor determining the production of the late crystallizing fractions, and indeed producing the diversity of terrestrial rocks as opposed to meteorites, may well be the retention of water in the terrestrial magmas. The production of a residual water-rich magma on earth must also have had important repercussions in the determination of vulcanism and so of the cycles of carbon, sulphur, and other atmophil elements of biological importance.

The distribution of the rarer elements in the different fractions follows certain rules emphasized by Goldschmidt. In general the entry of an ionized atom into the lattice of a silicate rock-forming mineral is determined by the ionic radius and ionic charge. Where the radii are essentially equal and the charges identical, the probability of any two atoms entering a lattice is equal. Where the radii differ but the charges are identical, the smaller atom has preference; we find for example the heavier alkalies and alkaline earths becoming more and more concentrated in the later fractions. Where the radii are identical but the charges differ, the atom with the greater charge has preference, so that the bivalent alkaline earths appear prior to the alkalies of like radius.

The first biological consequence of the process of fractional crystallization is the accumulation of aluminum in the relatively late fractions that produced the granite cores of the continental shields, for this process has, as we have seen, given the pedosphere its main characters, and may well, by providing a detoxicant of silica dust, and an adsorbant of various toxic materials in sea water, have largely determined the conditions of life on the globe.

The second biological aspect of the process of solidification of the crust, obvious to the geologist, practically unappreciated by the biologist, has been the removal of the enormous excess of magnesium in the early basic products of crystallization, so that in the accessible lithosphere the elements of the four major biological cations, Na, K, Mg, and Ca occur in quantities of the same order of magnitude, and in the later crystallizing rocks the concentration of magnesium may be quite low. Moreover, the enrichment of the rarer alkalies and alkaline earths in the later products of crystallization is most striking.

The biological importance of the redistribution of the major physiological cations is so striking that it requires no emphasis. The enrichment of the rarer cations has undoubtedly made them also more available to organisms. This is most striking in the case of barium, cosmically a relatively rare element, which, owing to its enrichment in potash feldspars, and other rock-forming minerals of the continents, is easily available in the biosphere. The great relative concentration of barium in soils is undoubtedly due to the behavior of the element in erosion and pedogenesis, but if it were not for its prior concentration by fractional crystallization it is certain that it would be far less easily detected in organisms than is actually the case.

	Ionic radius in lattice Å	*Silicate phase of meteorites* (Merrill, 1930, Goldschmidt, 1938) *Per cent*	*Upper lithosphere* (Clarke and Washington, 1924, Goldschmidt, 1938) *Per cent*	*Granite* (mean of eight analyses, by Hillebrand, for Na, K, Mg, Ca, Clarke, 1924; mean analyses of 14 specimens, Goldschmidt, Bauer and Witte, 1934, for Rb and Cs; Noll, 1934, for Sr; von Engelhardt, 1936, for Ba) *Per cent*
Na	0.98	0.77	2.83	2.37
K	1.33	0.20	2.59	4.64
Rb	1.49	0.0045	0.031	0.083
Cs	1.65	0.00001	0.0007	0.004
Mg	0.78	16.00	2.09	0.12
Ca	1.06	1.73	3.63	0.55
Sr	1.27	0.0026	0.015	0.017
Ba	1.43	0.0009	0.025	0.038

A third case is provided by gallium, indium, and thallium. Cosmochemically gallium is the commonest of the three, thallium the least common. In meteorites, both gallium and indium are somewhat siderophil, but terrestrially the association of gallium (Ga^{+++} 0.62Å) with aluminum (Al^{+++} 0.57Å) leads to an enrichment of gallium in the accessible lithosphere so that a supposed loss to the metallic core is of no great importance. Indium appears to be markedly siderophil, and though its behavior in the fractional crystallization of the silicate phase is not fully investigated the element is certainly not generally concentrated in the later fractions. Thallium, however, in its monovalent state behaves geochemically essentially like rubidium (Tl^{+} 1.49Å, Rb^{+} 1.49Å) occurring in potash minerals of late crystallizing fractions; occasionally up to 0.1 per cent has been recorded in potash feldspars. The result of these redistributions is to make indium far rarer in the biosphere than the cosmically less abundant thallium, so that while indications of biological functions can be given for both gallium and thallium, indium still remains entirely unknown in the living world.

A fourth case of biological interest is provided by the concentration of uranium in the later crystallizing fractions. This implies that the radioactive elements of the uranium and actinium series are more available in the biosphere than would be the case were the parent element not superficially concentrated. Vernadsky and his coworkers have placed much stress on these elements, though the

importance of radium and other strongly radioactive substances in the normal biochemistry of any organism can hardly be regarded as established.

A fifth case (Kidson, 1938) is provided by the separation of cobalt into the earlier ferro-magnesian fractions, the radius of Co^{++} being identical with that of Fe^{++} (0.78Å) and little less than that of Mg^{++} (0.82Å). The more acidic rocks, being thus depleted of cobalt, form soils poor in the element and so produce areas in which the supply of the element in the vegetation is inadequate for the support of domesticated mammals. This case is particularly interesting as it is probably the first example to have been discussed in print of the ecological significance of Goldschmidt's geochemical theories.

Finally chromium is a characteristic element of the products of early crystallization, though the problem of its terrestrial distribution is complicated by a marked tendency for this cosmically abundant element to enter the troilite (sulfide) phase of meteorites. The great reduction of the chromium content of the accessible lithosphere is, however, well established and may account for the rarity of the element in living matter and the failure of such a reactive multivalent metal to acquire a biological function.

The conditions limiting elementary migration in the biosphere

During denudation the ionic radius (r) and charge (z, i.e. the valency) play an important rôle, determining the ionic potential. Where the ratio z/r is less than 4, the elements tend to form cations that pass into solution at ordinary pH values. Where the ratio is greater than 12, the elements unite with oxygen to form freely-soluble anions. The elements whose ions have intermediate ratios tend to remain insoluble, as oxides or hydroxides. The position of certain important elements in this scheme naturally depends on the degree of reduction obtaining in the region considered. Divalent iron behaves as a soluble cation like magnesium, tervalent as a hydrolysate element like aluminum.

Since the time of Berthier (1826), who attributed the supposed absence of alumina in wood ashes largely to its low solubility, it has become evident that one of the most important prerequisites for an element to enter the living world is its capacity first to enter the hydrosphere. The most impressive example of this is the remarkable demonstration of Vernadsky, Brunowsky, and Kunasheva (1937) that the 8.25×10^{-17} per cent mesothorium I present in *Lemna* has entered the plant directly, being concentrated, along with its commoner isotope radium, a hundred fold over the quantity in the pond water supporting the plant. If any of the very insoluble parent element, thorium, is present in the plant it is in concentration less than 1 per cent of the amount in equilibrium with the MsTh I present. The amount of thorium in equilibrium with MsTh I is 3.3×10^{9} the amount of the latter, so that the maximum thorium content of *Lemna* is 2.7×10^{-10} per cent, which is of the order of 100 times the radium content, whereas thorium is about ten million times commoner than radium in rocks. We may conclude, with the authors, that thorium is practically not absorbed by *Lemna*, even though it is present in the pond water, presumably solely in suspension.

By far the most significant method by which solubility relations of biological interest can be expressed is by utilization of the diagram on which ionic radius and ionic charge are plotted. Again restricting the treatment to elements of essentially invariant valency in the oxidized parts of the biosphere, we find that above the line representing $\frac{r}{z} = 12$, we have the whole set of normal biological cations, below the line $\frac{r}{z} = 4$, the major non-metallic elements that form the organic compounds of living matter, other than oxygen and hydrogen which cannot be treated in this way. A further refinement is possible. If we consider all the elements of invariant valency for which there are adequate data, we can take the ratio of the quantity of the element in terrestrial vegetation, to the mean quantity in the accessible lithosphere. This has been done in Table 3.

Carbon and nitrogen are too atmophil to be treated in this way, though they obviously fall in the right part of the diagram. The ratios for boron, phosphorus and sulphur may be too high, in that supplementary sources of the elements other than erosion of silicate rock may be present. No other elements of constant valency in the biosphere can as yet be legitimately considered. Zirconium has only once been reported quantitatively from an organism, namely 0.001 per cent ZrO_2 in the ash of a specimen of *Aragallus lamberti* that contained 0.01 per cent TiO_2 (Crawford, 1908).

It is most improbable that zirconium is in general present in concentrations of the order of one tenth

TABLE 3

Ratio of the quantity of elements of invariant valency in terrestrial vegetation to the mean quantity in the accessible lithosphere

	(1) *Per cent in primary rocks*[a]	(2) *Per cent in living terrestrial plants*	(3) *Ratio* (2)/(1)
Cations			
Lithium[c]	0.0065	0.00001	0.0015
Sodium[b]	2.83	0.02	0.007
Potassium[b]	2.59	0.3	0.12
Rubidium[c]	0.031	0.0002	0.0066
Magnesium[b]	2.09	0.07	0.034
Calcium[b]	3.63	0.5	0.14
Strontium[c]	0.015	0.002	0.13
Barium[c]	0.025	0.003	0.12
Radium[d]	1.3×10^{-10}	$1\text{–}2 \times 10^{-12}$	≥0.01
Elements of hydrolysates and residua			
Rare-earths (Y + lanthanides)	0.0148	0.00004	0.0027
Aluminum	8.13	0.002	0.00025
Titanium[c]	0.64	0.0002	0.00032
Silicon[b]	27.72	0.15	0.0055
Elements of complex anions			
Boron[e]	0.0003	0.0005	1.7
Phosphorus[b]	0.08	0.07	0.88
Sulphur[b]	0.052	0.05	0.96
Vanadium[f]	0.015	c. 0.00002	0.0013
Molybdenum[g]	0.0015	0.00005	0.033

[a] From Goldschmidt 1938, in part after Clarke and Washington 1924.

[b] From Vinogradov 1935a.

[c] Evaluated from Robinson, Steinkoenig, and Miller (1917) supplemented by numerous recent papers.

[d] Brunowsky and Kunasheva (1935).

[e] From data summarized by Beeson (1941) admitting only whole plants or samples based on the greater parts of plants; dry weight taken as 10 per cent of wet weight. Vinogradov gave a higher figure, 0.001 per cent. In view of Robinson and Edgerton's (1942) results for the hickory, it is possible that the figure given above is too low, but Vinogradov's is probably too high.

[f] D. Bertrand (1941b): given as about 1 mg. per kilo dry.

[g] D. Bertrand (1940).

the titanium content and it is therefore fairly safe to conclude that the ratio for this element and doubtless also for hafnium is below 0.001. Carrigan and Rogers (1940) find that zirconium is normally present in Florida soils but is never observed to pass into plants, in a few of which titanium was spectrographically detectible.

It is now possible to draw contour lines on the diagram, as has been done in Fig. 7. The contours containing those lithophil elements of invariant valency with ratios in excess of 0.1 and 0.01 will enclose two fields, one in the soluble anion section, the other in the cation section of the diagram. The area enclosed by the contour within

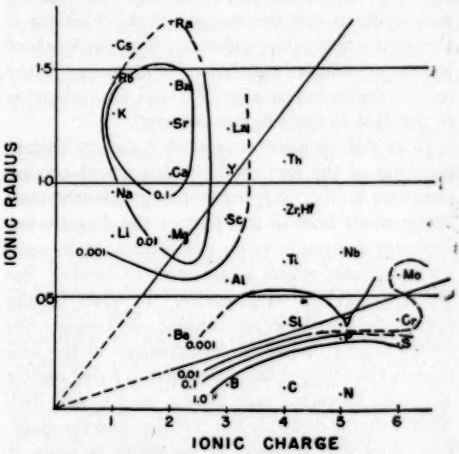

FIG. 7. GOLDSCHMIDT'S DIAGRAM INDICATING THE FATE OF LITHOPHIL ELEMENTS OF CONSTANT VALENCY DURING DENUDATION, MODIFIED TO SHOW THE EFFECT OF SOLUBILITY ON THE COMPOSITION OF TERRESTRIAL PLANTS

which lie those elements whose ratio is less than 0.001 will form a narrow diagonal area in the middle of the central hydrolysate section of the diagram. This arrangement, together with the cosmic abundance of the light elements of biological importance, underlies the direction of the *Nährstofflinie*, drawn by Frey-Wyssling (1935) on the periodic table.

The most unfortunate uncertainty involves the position of strontium. The only considerable body of data is given by Robinson, Steinkoenig, and Miller (1917) whose mean for all plants analyzed is 0.007 per cent Sr in the dry matter, and for the woody parts of shrubs and small trees 0.008 per cent Sr in the dry matter. These figures correspond to a mean

value between 0.001 per cent and 0.004 per cent of the living plant. Headden (1921) and Collander (1941) give data for herbaceous plants grown on Colorado and Finnish soils respectively, corresponding to rather less than 0.001 per cent of the living matter. De Rubies and Lemmel (1935) appear to have found much less strontium than barium in wood ashes but little significance can be attached to their quantitative results. The technical discussion of Robinson, Steinkoenig, and Miller indicates that their strontium nitrate preparations were contaminated with little calcium, but that some strontium may have been lost. The estimate of 0.002 per cent is therefore probably conservative. Collander's experiments with solution cultures suggest that strontium is absorbed exactly like calcium; since the work of Robinson indicates enrichment of strontium in the soil, it seems improbable that the interpretation of the data in the diagram is forced.

It is not possible to consider the individual elements of the rare earths which would occupy positions in the diagram just below lanthanum. The contour lines in this part of the diagram are arbitrary inasmuch as no independent data exist for scandium, which is assumed to behave like yttrium and the lanthanides. In view of the extremely low thorium content of *Lemna*, one would expect cerium, if quadrivalent in the biosphere, to be proportionately lower in living matter than the tervalent rare earths as La and Nd. This is almost certainly not the case, and the quantity of cerium retained in sea-water is more in accord with behavior as a tervalent element. It has been claimed possible that in rooted vegetation thorium is not as rare as in *Lemna*. The only data, from which a mean value of 4.5×10^{-5} per cent, corresponding to a ratio of 0.04, may be derived, are admitted unsatisfactory (Burkser, Kondoguri, Milgewska, and Bronstein, 1931), and may be rejected as much too high. The right-hand ends of the 0.01 and 0.001 anionic contours are uncertain, owing to the lack of reliable data for chromium. Robinson, Steinkoenig, and Miller report 0.008 per cent Cr_2O_3 in the dry matter of one sample of red clover, and 0.004 per cent in one of timothy grass. In the forty-six other samples studied traces of chromium were found in thirteen. The sensitivity of their method in general allowed recognition of 0.001 per cent. The mean content of terrestrial plants would therefore appear to be not greater than 0.0001 per cent of the living matter. Since Goldschmidt (1938) gives the chromium content of the accessible lithosphere as 0.02 per cent, such a quantity would correspond to a ratio of ~ 0.005. If such a value be established, the anomalous position of molybdenum relative to both vanadium and chromium is emphasized. It is, however, to be noted that Robinson, Steinkoenig, and Miller considered their test for molybdenum as sensitive as that for chromium, yet they never encountered the former element. Moreover, it is possible that neither chromium or molybdenum can be admitted to the diagrams, no proof of their sexivalent nature in the biosphere being available.

A further anomaly may possibly be implied by Baranov's conclusion that actinium is taken up more readily by plants than are the other strongly radioactive elements. It is, however, quite uncertain which members of the actinium disintegration series are actually absorbed.

THE SOIL AND THE OCEAN

While the cycles of the majority of the more important substances have been elucidated in the soil and in the ocean by pedologists and oceanographers, the physical dissimilarity of the two great storehouses of biological elements has discouraged any adequate comparison of the cycles in the pedosphere and hydrosphere.

The problem is of particular interest in relation to the present review, inasmuch as it seems desirable as far as possible to generalize current conceptions of the rôle of the hydrolysate elements in adsorption, and also because some unexpected light is cast by the comparison on the biogeochemistry of europium. In order to facilitate the procedure we may again employ Goldschmidt's diagram, the utility of which has become apparent in the preceding section, and consider the lithophil biological elements in three categories.

(1) The non-metallic elements of primary importance in the composition of organic compounds, namely carbon, nitrogen, phosphorus, sulphur, and possibly boron.

The cycles of such elements in both sea and soil are primarily biochemical and are comparable in the two geospheres under consideration.

(2) The hydrolysate and residual elements, aluminum, titanium, zirconium, silicon, and perhaps beryllium, with which may now be included the oxidate elements, iron, manganese, and perhaps gallium, the biological availability of all of

which is primarily restricted by low solubility in neutral aqueous solvents.

The distribution of such elements is presumably determined partly by the distribution of the solid phase of their compounds, partly by the conditions for its solution. Neutral aqueous media will dissolve little of any of them. Such of the elements that can form complex anions (e.g. Si, Al) will appear in alkaline solutions; such as can form cations (e.g. Al, Fe^{+++}) in acid media. In general, conditions permitting reduction will permit higher concentrations of the oxidate elements (Mn, Fe). Usually the pedosphere will be more favorably placed for the solution of such elements, particularly when it is remembered that the solution may take place under the direct influence of the root hairs of plants.

It has been pointed out (Harvey, 1937) that marine diatoms may also provide an acid and reduced zone around their cells that can dissolve and utilize ferric hydroxide or phosphate, but in such cases the absolute concentration of the element in the solid phase becomes important, in that it is necessary to consider the probability of encounter of such cells with the solid particles under consideration.

The concentration of aluminum, and also of titanium, in terrestrial plants dependent on the soil, in marine animals dependent on sea water, and terrestrial mammals dependent on terrestrial plants, may be profitably compared.

	Terrestrial plants (mean per cent wet weight)	*Marine invertebrates (mean per cent wet weight)*	*Terrestrial mammals (mean per cent wet weight)*
Al.....	0.002	0.000n	0.00005
Ti*.....	0.0002	0.00008	0.000002

* Robinson, Steinkoenig, and Miller (1917); Geilmann (1920); Bertrand and Voronca-Spirt (1929, 1930a, b); Askew (1930); Kaminskaja (1937); I. and W. Noddack (1940).

There is clearly a general tendency for terrestrial plants to contain more of these two elements of intermediate ionic potential than do the other two groups of organisms. In the case of the terrestrial mammals the concentrations imply a rejection of elements not important in their metabolism.

(3) The cations, which group may be taken provisionally as consisting primarily of the alkali and alkaline earth elements.

The history of the cations is bound up on the one hand with their behavior in relation to aluminosilicate complexes in the soil, on the other with behavior in relation to sedimenting hydrolysates in the ocean. Since the hydrolysate materials of the soil form a more or less permanent part of the structure of the pedosphere, cations retained by any adsorption process are conserved in that geosphere, while in the ocean the same processes, taking place on sedimenting particles of hydrated oxides and clays result in a loss of elements from the hydrosphere. Superficially considered, the history of the cations is therefore likely to be reciprocal in the two geospheres. Actually, when the effect of the presence of hydrolysate minerals is examined in detail, various special properties of the elements obscure this deductive reciprocity.

Considering first the alkaline earths, the relative quantities in meteorites and the various geospheres appear to be as follows:

	Mg	*Ca*	*Sr*	*Ba*
Silicate meteorites....	925	100	0.15	0.05
Accessible lithosphere.	57.6	100	0.41	0.69
Soils (Robinson, 1914).	68.7	100	7.2	13.1
Ocean.....	310	100	~ 2	≤ 0.01

The data for soils are restricted to a single series of analyses, which alone give all the information required. The data for barium are, however, confirmed by Failyer (1910) and Bertrand and Silberstein (1928) whose results also indicate an enormous concentration of barium in the pedosphere. Even though certain igneous rocks may produce soils particularly rich in barium, while calcareous sediments may give rise to soils with the ratio abnormally in favor of calcium, it seems certain that in the mean soil, derived from the primary rocks of the continents, the Ca:Ba ratio is of the order of 100:10. In the sea this ratio is immensely in favor of calcium. This particular case of marked reciprocity of behavior is doubtless partly due to a special property, the low solubility of $BaSO_4$, as well as to the energy with which barium is held by colloidal clays. Since Failyer found much barium could pass into solution when soils were leached with water containing CO_2, and since fresh waters in general are probably far from saturated with $BaSO_4$, the adsorption of barium ions is doubtless of great importance. In lakes, Hutchinson, Wollack and Setlow (1943) find that barium apparently follows the silt fraction in sedimentation, while calcium and strontium are precipitated together, mainly in alkaline waters.

Strontium appears to behave like barium in soils, though the data are inadequate, being limited to the determinations of Robinson. In the sea there is an extensive loss of the element, but this is not quite as great proportionately as in the case of calcium (Goldschmidt, 1937). Strontium probably provides a fair case of reciprocal behavior of the type deductively postulated.

At the opposite end of the series, the relation is less conspicuous, for although magnesium is least easily removed from the sea by adsorption, as is in harmony with the behavior of the element in laboratory experiments, it is not clearly lost from the pedosphere more easily than calcium. In three series of soils in North America, compared with the accessible lithosphere, we find:

	*Accessible lithosphere**	*466 humid soils (southern)* Clarke, 1924, after Hilgard	*313 arid soils (western)* Clarke, 1924, after Hilgard	*13 soils (eastern)* Robinson, 1914
Mg.....	2.09%	0.136%	0.85%	0.333%
Ca.....	3.63%	0.078%	0.98%	0.486%
Mg per 100 Ca.	57.6	175	91.4	68.7

* The recent recalculation by Kuenen (1941) gives 1.91 per cent Mg, 3.43 per cent Ca, and a ratio of 55.8.

Although both elements are removed, but at very different rates under different climatic conditions, as is well known, there is a persistent tendency for magnesium to remain in quantities in excess of the expected geochemical ratio. In view of the large number of samples involved this is not likely to be due to an overrepresentation of ferromagnesian parent rocks. It will be remembered that magnesium is an integral part of certain of the montmorillonic series of clays.

Calcium is, like magnesium, lost from the soil by leaching, rather than enriched as is the case with the heavier earths. In the ocean the calcium content is probably mainly under biological control. Kuenen (1941) believes that until the evolution of the pelagic foraminifera, the ocean was markedly supersaturated with calcium, and the neritic seas milky with colloidal or finely suspended chalk. This, deposited on the continental shelves, could, by uplifting and erosion, reenter the cycles of the soil and of fresh waters. Since the evolution of the pelagic foraminifera in the Mesozoic, vast amounts of calcium have been deflected into the sediments of the permanent basins, and in the remote future the continents will suffer from a relatively intense shortage of lime. This diversion of calcite into the depths of the ocean presumably explains the slightly greater retention of strontium, for strontium is excluded from the calcite lattice. A quantitative description of the process of calcium loss might in fact be derived from a comparison of the strontium and calcium delivered and retained by the ocean. Unfortunately the data on strontium are not good enough to justify such an attempt at the present time.

That the three heavier alkalies should be removed progressively more completely from the ocean (Goldschmidt, 1937) is in accord with their behavior in adsorption experiments in the laboratory. We should therefore expect at least a relative enrichment of caesium over rubidium, and rubidium over potassium in soils. No adequate data exist for caesium, but for rubidium Robinson's figures suggest that the ratio of the mean potassium to the mean rubidium content is about 100:0.14, while for primary rocks the relative rubidium content is apparently almost ten times that of the soil, the K:Rb ratio being 100:1.2. This difference cannot be regarded as due to a biological loss of rubidium into plants, for in the latter the ratio is essentially as in the soils on which they grow. Marine animals, according to Fox and Ramage (1931), never contain more than 0.002 per cent Rb in the dry matter and usually apparently much less; the maximum content would correspond to a ratio of 100:0.1. The rubidium of the ocean corresponds to a ratio of 100:0.05. It is therefore improbable that rubidium is concentrated relative to potassium in marine animals. These facts emphasize the highly individual behavior of the elements in the comparison between sea and soil, but are perhaps also potentially significant from another point of view. As is well known, Macallum (1926) has postulated that the original ocean was far richer in potassium than the modern ocean, at least relative to the sodium content, and considers that the general high K:Na ratio of cells is due to retention in the cytoplasm of the general ionic balance of the primitive home of life. Macallum's geochemical evidence, often accepted by biologists, is entirely unconvincing. However, if we regard the removal of the heavier alkalies as the result of adsorption on sedimenting hydrolysate-oxidate

minerals, it is obvious that this process is a function of pH. Moreover, if initially the hydrosphere were quite acid, as Lane (1917) supposes, the hydrolysates would not be formed, or would dissolve on reaching the ocean. There is a possibility, therefore, that Macallum's hypothesis is correct. Pantin (1931) has derived a purely physiological scheme, based on ionic mobility and the establishment of a steady state in the ionic composition of the cell. This hypothesis, as stated, implies that marine animals should concentrate rubidium. Macallum's theory in its simplest form presumably implies, if the acidity of the ancient ocean be accepted, a high rubidium content in the early environment of organisms. The rubidium content of organisms, in so far as it is known, therefore appears to contradict both Pantin's largely physical theory and Macallum's more imaginative approach. The latter, however, in its very remoteness offers more degrees of freedom and may be susceptible of modification when more is known of the cycle of rubidium in the biosphere. At present the data are so inadequate that speculation is only justified as a means of ascertaining the nature of the worst lacunae in our knowledge.

Sodium, like magnesium, accumulates largely in the sea, and is indeed the only metal retained in the ocean in quantities at all comparable to those delivered. The ratio of Na:K strongly suggests a marked reciprocity in behavior.

	Na		*K*
Accessible lithosphere	109	:	100
Ocean	2727	:	100
Soils, southern U.S.A. (humid)	37.9	:	100
Soils, western U.S.A. (arid)	32.0	:	100
Soils, mainly eastern U.S.A.	36.4	:	100

The various soils included are very diverse, and the general equivalence of the ratios, representing about three potassium atoms to two sodium atoms, is very striking. Yet when the matter is prosecuted further, it is found, as far as the rather unsatisfactory data permit an estimate, that in the exchange atmosphere of soil colloids, sodium ions outnumber potassium by at least two to one, though they are themselves greatly outnumbered by calcium ions, while in the elementary composition of hydrogen or calcium-saturated colloidal minerals responsible for base exchange, potassium is in excess, as in whole soils.

	Na		*K*
Replaceable ions present in situ (Kelley and Brown, 1924)			
Seven neutral or slightly alkaline California soils	130	:	100
Miscellaneous acid U. S. soils	257	:	100
Alkalies in the base exchange mineral colloids			
Eight California groups of soil colloids (Kelley, Dore, Woodford, and Brown, 1939)	31.4	:	100
Ten western arid soil colloids	44.4	:	100

It appears, therefore, that the diagrammatic type of reciprocity shown in a comparison of the behavior of sodium and potassium is not simply the result of base-exchange adsorption, but is related to the retention or fixation of potassium in a special way by the soil colloids, presumably mainly between the sheets of the illite group of clays.

Speculations on europium

This long digression has at least served to elucidate one of the most curious features of Fig. 7, namely the inclusion of barium and strontium within the highest cationic contour. These elements have now appeared as intensely pedophil, and though they may not be absorbed by plants as readily as calcium, they have a great relative advantage in the soil, which advantage determines the position of the 0.1 cationic contour in the diagram. Such a result makes possible an interpretation of the apparently excessive europium content of terrestrial plants. Europium is the only lanthanide likely to occur in the biosphere as a stable bivalent ion. In the europous state, europium has an ionic radius (1.17Å) and general physical chemistry comparable to that of strontium, and many strontium minerals are known to be enriched in europium. We should therefore expect an enrichment of bivalent europium in soils. This is apparent in Russian soils, as has been previously indicated, though the high lutecium content is less expected. The europium is apparently transferred to the plant and at least in North American material appears as a more conspicuous element than would have been postulated on purely geochemical grounds. This very curious feature of the biogeochemistry of the rare earths is therefore concordant with the known

types of migration in the soil, even if the exact mechanism of the enrichment of strontium in the pedosphere remains to be elucidated. In view of the existence of relatively stable europous and europic salts the possibility that some of the organisms that accumulate the element can adapt it to their biochemical needs is not as remote as might appear at first sight.

BIOGEOCHEMISTRY AND CELLULAR PHYSIOLOGY: THE PRIOR PROBABILITY THAT AN ELEMENT HAS A FUNCTION

The previous sections have shown that a completely impartial intelligence, quite unfamiliar with biochemistry, though well versed in the physical sciences, might assess with some accuracy the probability that any given element would play a large or small part in the colloidal systems, dispersed in water, that constitute the bodies of living organisms. Common elements would be more likely to occur than rare elements, elements usually soluble, more likely than highly insoluble elements, superficially concentrated elements more likely than those largely lost to the metallic core of the earth. Hydrogen would be given a far higher prior probability than aluminum, aluminum a far higher prior probability than indium. As this imagined being proceeded with his biochemical education he would find many of his suspicions confirmed.

The biologist, recovering from the shock of so non-biological a view of the organism, may point out that, knowing *a posteriori* the actual distributions, it is easy to see how the prior probabilities should be assessed. (For the importance of the concept of prior probability, the biologist will do well to consult Jeffreys, 1937, 1939.) Moreover, it seems certain that in some cases, as for instance that of the relative importance of strontium and manganese, a purely geochemical assessment would lead to the wrong result. It can also be objected, that, in the consideration of solubility relations, the metals of greatest biological interests are excluded by limitation of the treatment to lithophil elements of essentially invariant valency. Nevertheless, it is so remarkable that any results of the kind implied by the contours of Fig. 7 can be obtained, that an attempt to approach nearer to the more intimately biological problem of function, along geochemical lines, would seem to be justified.

If the matter be examined first in the broadest possible way, a considerable number of elements (H, O, C, N, S, P, B, K, Na, Ca, Mg, Si, Al, Cl, Br, I, Fe, Mn, Zn, Cu, Mo, Co, V, Sc, Ga, Tl, Se, ? As, and in skeletal structures F, Sr, and Ba), have, under some conditions, a function, or form an integral part of the chemical or morphological structure of one or more kinds of organism. In general, these elements are present, at least in some organisms, in quantities in excess of 10^{-7} per cent of the living matter.

A second group of elements may be distinguished pragmatically, occurring in some organisms in quantities of the same order of magnitude as the scarcer members of the first group, but at present of no known function (Li, Rb, Cs, Be, Cd, Hg, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Yb, Ti, Zr, ? Th, Ge, Sn, Pb, Sb, Bi, ? Nb, U, Ni, Ag, Au, Pt).

As a result of the studies of Vernadsky's associates, the strongly radioactive elements are known to occur in amounts of the order of magnitude of 10^{-12} to 10^{-17} per cent. Between the chemically and spectroscopically detectible elements of the first two groups, and the radiochemically detectible elements, there lies a region of so far undetected elements of orders of magnitude of abundance from 10^{-7} to 10^{-12} per cent, including presumably most or all of the non-radioactive elements so far not enumerated (Tu, Lu, In, Ta, W, Hf, Te, Re, Pd, Rh, Ru, Os, Ir). These are so much commoner in the lithosphere than is radium, that unless they are actively excluded, they are presumably commoner in living matter than are the strongly radioactive elements.

If we consider a restricted group of organisms, the number of elements of known function is obviously restricted. For the mammalia the functional group would presumably comprise:

H, O, C, N, S, P, K, Na, Cl, Ca, Mg, Fe, Mn, Zn, Cu, Al, Co, I, and possibly F and Br;

the group of non-functional but recorded elements:

Li, Rb, Cs, Sr, Ba, Hg, Cd, B, Ga, Sc, Y, La, Ce, Nd, Gd, Dy, Si, Ti, Ge, Mo, Sn, Pb, As, U, ? Se, Ni;

and the non-radioactive elements not known to be present:

V, In, Tl, Be, Pr, Sm, Ho, Er, Tb, Tu, Yb, Lu, Zr, Hf, Th, Sb, Bi, Nb, Ta, Te, Cr, W, Re, Au, Pt, Pd, Rh, Ru, Os, Ir.

It would obviously be of interest to attempt to gain some insight into the biochemical possibilities

of the recorded elements of no known function, and into the prior probability that some of the undetected elements may yet be found to have a biological rôle.

We may in the first place enquire into the limits of dilution at which known substances are biologically active. The best established case of the action of a substance at an excessively low concentration is the dependence of the growth of certain strains of yeast on the biotin content of the medium. Snell, Eakin, and Williams (1941), using a particular strain of *Saccharomyces cerevisiae* recommend 10^{-11} g. biotin made up to a final volume of 5 cc. as a suitable concentration for the lowest standard culture used in the preparation of a calibration curve in the bioassay of biotin. Dr. Paul R. Burkholder, in some determinations made in conjunction with the writer (Hutchinson, 1943) on the biotin content of lake waters, finds a detectible effect at 5.10^{-12} gm. in 5 ml. cultures. The empirical formula of biotin is $C_{10}H_{16}O_3N_2S$, corresponding to a molecular weight of 244. The absolute mass of a biotin molecule is therefore $244 \times 1.63 \times 10^{-24}$ gm., or roughly 4.10^{-22} gm. A yeast cell of diameter of 20 μ or volume of roughly 4.10^{-9} cc. will therefore occupy the same space as would contain, on an average, 10 biotin molecules in the most dilute active preparation of the substance. This of course does not imply that there are but 10 molecules in the cell; the partition coefficient between cells and medium at the end of an experiment is not known, though it must be greatly in favor of the former. It is, however, clear that the yeast cell can deal effectively with substances presented to it a few molecules at a time. Of the substances recently tabulated by Green (1941) as active at great dilutions, the melanophore stimulant of the pituitary, in a crude preparation, exhibits comparable activity, though its chemical nature is unknown. At least one claim has been made, namely by Kühn, Moewus, and Jerchel (1938) that the influence of a single molecule on a cell can be detected. This is asserted for the effect of crocin in producing motility of the flagella of *Chlamydomonas eugametos* f. *simplex* reared anaerobically in the dark. The work has, at least, never been disproved.

There is, moreover, evidence of a more general kind from genetics that a change involving a few individual molecules may be of importance to the cell. Otherwise it is difficult to explain the continued recurrence of a limited number of multiple alleles in a locus such as white on the first chromosome of *Drosophila melanogaster*. If a large number of similar molecules (or homologous parts of bundles of fibrous molecular structures) constituted a gene, the chance of *discrete* alterations in a few directions would be very small indeed. Moreover, where a gene has a low but rather constant penetrance under given conditions, it is hard to avoid the assumption that the phenotypic expression of the gene is determined by the probability of occurrence of an event that might be of molecular dimensions; and as Dr. Donald F. Poulson suggests, phenomena comparable to low penetrance are doubtless also involved in caste determination in social insects, as analyzed, for instance, by Gregg (1942). Rahn (1943), moreover, regards the logarithmic order of death in bacteria as due to induced lethal mutations affecting monomolecular genes. Consideration of such observations suggests that there is no reason, merely on the grounds of rarity, to exclude from consideration substances occurring in concentration of an order of magnitude of ten molecules per cell. An *average* content of a single molecule per cell, however, is almost certainly beyond the limit of significance unless, as in the chromosomes, very special structures prevent random variation from depriving some cells of their molecular portion altogether.

Green (1941) has pointed out that all the materials, either trace elements or vitamins, needed by organisms in very minute quantities, probably act as cofactors or prosthetic groups of enzymes. This is known to be true of copper, zinc, and aluminum among the inorganic trace substances, and of thiamin, pyridoxine, and nicotinic acid among the vitamins. Biotin doubtless acts in this way, but there is no reason to suppose that it is the rarest of all organic substances of like function. Green also suggests that other substances, such as certain hormones, active at like concentrations, may function by inhibiting enzymatic reactions.

We may now consider the atomic concentration of various trace elements within the cell, taking as an example the mammalian liver-cell, which has a diversity of function, has often been analyzed and shows little variation in dimensions. The mean diameter for such a cell, from the data assembled by Pfuhl (1932) is 23.4 μ. Assuming a spherical shape, an arbitrary but necessary convention, the volume is found to be 6720 μ^3. Assuming a density slightly greater than unity the mass may be taken approximately as 7×10^{-9}

TABLE 4

Mean numbers of various kinds of atoms and molecules in the mammalian liver cell

*Zinc[a, b]	4,200,000,000 (170,000,000–13,000,000,000)	$n \times 10^9$
Lithium[a]	1,800,000,000 (180,000,000–5,500,000,000)	
Rubidium[a]	680,000,000 (85,000,000–4,100,000,000)	$n \times 10^8$
*Copper[a, c, d, e]	350,000,000 (53,000,000–9,000,000,000)	
*Manganese[a, c, f]	220,000,000 (39,000,000–500,000,000)	
*Aluminum[g]	190,000,000 (47,000,000–580,000,000)	
Tin[c, h]	88,000,000	$n \times 10^7$
*Pyridoxin[i]	*59,000,000*	
Titanium[j]	44,000,000	
Molybdenum[e]	43,000,000	
*Cobalt[k]	14,000,000	
*Biotin[i]	*14,000,000*	
Lead[c, l]	10,000,000	
Strontium[a]	9,700,000	$n \times 10^6$
Nickel[m]	7,000,000	
Silver[c]	2,000,000	
Uranium[n]	840,000	$n \times 10^5$
Mercury[c]	550,000	
.....	.....	.....
Radium[p]	23	$n \times 10^1$

[a] Lundegårdh and Bergstrand (1940) and mean data referred to wet weight, quoted therein: man.

[b] Bertrand and Vladesco (1920): horse; Bertrand and Brandt-Beauzemont (1930): adult rat.

[c] Kehoe, Cholak and Story (1940a): man.

[d] Boyden, Potter and Elvehjem (1938): normally-fed rat.

[e] Ter Meulen (1931): ox, pig, man (Mo only). The technique for molybdenum is criticized by Dingwall, McKibbin, and Beans (1934) but Ter Meulen's results on plants are confirmed by D. Bertrand (1940).

[f] Bertrand and Medigreceanu (1913): seven species; Reiman and Minot (1920): man.

[g] Data summarized in an earlier section of this paper; Lundegårdh and Bergstrand give much higher values from man; their mean corresponds to 4,300,000,000 atoms per cell.

[h] Bertrand and Ciurea (1931): ox, sheep, horse.

[i] Mitchell and Isbell (1942): rat; Taylor, Pollack and Williams (1942): man.

[j] Bertrand and Voronca-Spirt (1930b): horse, ox, sheep, pig, rabbit.

[k] Bertrand and Mâcheboeuf (1925b): man, ox.

[l] Ciurea (1931): horse, sheep, ox.

[m] Bertrand and Mâcheboeuf (1925a): man, ox.

[n] Hoffmann (1942 and an earlier analysis quoted therein): ox.

[o] Stock (1940); man (uncontaminated material only; one abnormal case omitted).

[p] Krebs in Rajewsky (1939): man.

Grateful acknowledgment is made to Dr. Oskar Baudisch and Dr. Werner Bergmann for references that have added materially to the completeness of this table.

gm. Using this figure and a normal water content of 70 per cent when the analytical data are referred to dry matter, we can calculate the masses and so the numbers of atoms of the trace elements known to occur within such a cell. The results of these calculations are set out in Table 4; the mean numbers of molecules of the two scarcest vitamins have also been entered. Substances known to have a biological function are marked with an asterisk. For the first five elements the ranges found in man by Lundegårdh and Bergstrand (1940) are entered, for aluminum the range implied by Table I of the present paper is also given. These data indicate the considerable variation encountered in the better-known cases. For the scarcer elements, for which it is not yet possible to gain an adequate idea of the variation, a similar amplitude may be confidently expected.

Examining the table we find that all the elements entered, save radium, are present in quantities greatly in excess of the theoretical lower limit for function that has just been established. Moreover, enough is known about the functional significance of five of the ten elements present in concentrations of from 10^7 to $n \times 10^8$ atoms per cell to indicate that any further element subsequently found present in a concentration of the order of 10^8 atoms per cell is at least as likely as not to have a biological function.

The position of biotin, and of cobalt, indicates that a concentration of 10^7 molecules or atoms per cell may be highly significant physiologically. There is, however, no reason to suppose that a sharp arbitrary limit is set at 10^7. Since there is, on theoretical grounds, a definite, though doubtless very small prior probability of function for any substance present in concentration of the order of $n \times 10$ atoms per cell, and a highly significant

prior probability of function, of the order of 0.5 for any new member of the part of the range to around 10^8 atoms per cell, the prior probability of function for some of the numerous elements that must lie in the immediately adjacent range, say from 10^5 to $n \times 10^6$ atoms per cell, therefore appears high enough to justify a more intense study of the rarer trace elements in animal physiology than has hitherto been undertaken. The history of the discovery of the normal rôle of aluminum in the succinoxidase system, in spite of the negative results of deficiency experiments, suggests that direct enzymological studies are more likely to yield information of interest than is the nutritional approach. The apparent negative results of recent investigations with molybdenum (Teresi, Elvehjem, and Hart, 1942) and with vanadium (Daniel and Hewston, 1942) do not therefore entirely exclude the possibility of a normal function for these elements in mammalian metabolism. On both chemical and comparative grounds nickel, chromium, cadmium, tin, and gallium are likely to provide interesting possibilities. A striking feature of the table is the appearance of cobalt at a higher concentration than that of nickel. In plants (Bertrand and Mokragnatz, 1925) and in the lower metazoa (sponges, coelenterates, and some molluscs and tunicates; Fox and Ramage, 1931; Paulais, 1936; I. and W. Noddack, 1940) the ratio of nickel to cobalt appears normally to be about 10:1, but in certain of the higher invertebrates and notably in the vertebrates, the cobalt content is considerably increased, as if an important new function for the latter element had been evolved in the more complex animals. Rubidium and lithium, the two most abundant elements that are not known to play a physiological part in mammalian metabolism, doubtless enter the cell along with potassium and sodium respectively, and their abundance does not necessarily imply a high probability of function.

If the preceding considerations indicate that some surprises are probably in store for the mammalian biochemist, they also tend to dispose of the belief that has been widely cherished by certain schools of investigation, that the natural strongly radioactive elements play a part in normal biochemistry. The mass of a radium atom is 3.7×10^{-22} gm. A cell of mass 10^{-12} gm. and so of linear dimensions of the order of 1 μ, would have to contain at least 3.7×10^{-8} per cent Ra for each cell to contain on an average one atom. This consideration alone suggests that radium is very unlikely to play a part in the metabolism of the bacteria, for the amount required would be vastly in excess of that recorded from the higher organisms. In the average mammalian liver-cell, discussed above, containing a mean number of 23 radium atoms per cell, a chemical function is just conceivable. In yeast cells, the quantity recorded by Brunowsky and Kunasheva, namely 5.0 to 9.3×10^{-13}, certainly implies less than one atom per cell. The quantities (0.87 to 4.6×10^{-12}) present in the much larger cells of green plants presumably represent an accumulation of more than a single atom in the average cell. Claims of stimulatory action by the strongly radioactive elements have long been made; the only experiments clearly bearing on a possible normal function for radium, actinium, and uranium, are those of Baranov (1939), who concludes that the optimal concentrations of Ra, U free from Ra, and Ac with its decomposition products, correspond to about 3.8 atoms decaying per 100 ml. per min. Assuming that the plant concentrates the element tenfold, the optimum content would imply a mean incidence of one disintegration in a cube of face length 0.1 mm., every five years. In view of the limited numbers of atoms present in each biologically functional unit, it is obvious that even if radium ultimately prove to be a biologically functional element, which to the present writer seems rather improbable, the chances of its function being dependent on radioactive properties are negligible. In most cases the few radium atoms present are unlikely to disintegrate within the life of the cell, which is very short compared with the half-life of the element.

The possible relationship of widespread physiological function to the phenomenon of elementary accumulation, such as is shown in the case of aluminum by the *Lycopodiaceae*, *Orites*, *Diapensiaceae*, *Melastomaceae*, and *Symplocaceae*, raises interesting problems. It would seem likely that accumulator organisms have arisen through a hypertelic evolution of the normal mechanisms involved in the uptake of small amounts of trace elements. In ordinary cells these substances are clearly strictly localized, as is indicated by the dilution effects caused by homogenization, and by the fact that enzyme systems and highly inhibitory metals can coexist in the same cell. Any evolutionary process tending to increase the uptake

of a single element will in all probability affect a definite region of cell structure in a specific way. It is most improbable that the whole system of the region will evolve proportionately. Zinc has only one known function in the cell, namely as part of the enzyme carbonic amhydrase. Yet the zinc content of the viscera of *Gryphaea angulata* is so great that if the element retained its normal function, the greater part of the mass of the animal would consist of the enzyme. This is unlikely, as there is no traditional prejudice against the consumption of any of the edible *Ostreidae* with champagne. It is, however, not unreasonable that parts of the system besides the element accumulated might undergo a great parallel evolutionary increase. It is, therefore, very tempting to explain the curious accumulation of aluminum basic succinate in *Orites* as a parallel evolution of mechanisms for bringing succinate and aluminum into the same sphere of influence, without a parallel development of the enzymatic machinery of oxidation.

Considerably more data are required to elucidate the meaning of all cases of striking non-skeletal accumulation. The most certain cases appear to involve, besides selenium and aluminum in plants, manganese, zinc, and vanadium. Only for the first and last elements are no normal functions known; the occurrence of vanadium in quantities both in certain tunicates and in one holothurian would be more easily understood if the element finally proves to play a widespread part in animal metabolism.

One final aspect of the cellular distribution of the trace elements must be mentioned. There is good evidence that the various enzymatic systems with their metallic co-factors or prosthetic groups may be localized within the cell in such a way that in the immediate vicinity of the system there is maintained a locally high concentration of metallic ions. It appears also from the work of Horecker, Stotz, and Hogness (1939), that in the case of the succinoxidase system, zinc is highly inhibitory while aluminum is required. It is, however, reasonably certain that both zinc and aluminum-containing systems must exist in the same cell, and be in equilibrium with free zinc and aluminum ions within small and apparently more or less isolated regions. It is also noteworthy that Kharasch, Legault, Wilder, and Gerard (1936) have shown that a substance exists in beef extract inhibiting the catalytic oxidation of certain thiol systems by iron, but not affecting catalysis by manganese or copper, and that another substance in liver inhibits catalysis by iron and copper but not by manganese. Furthermore, Kharasch, Conway, and Bloom (1936) found that liver extract could abolish the inhibition of pigment production in *Staphylococcus aureus* produced by copper, but not the inhibition produced by manganese. They also obtained evidence of continued, though highly abnormal, growth of *Chlorella vulgaris* in the presence of toxic concentrations of copper, if liver extract were added. Though certain features of their experiments remain problematical the effects observed may reasonably be attributed, as the author points out, to the formation of complexes and a great diminution of the number of free ions, on the addition of the extracts. It is is important to note that the effects are highly specific, and cannot be attributed to vaguely defined phenomena of adsorption.

There is no reason to suppose that the known quantities of the rarer physiologically active materials, of the order of 10^7 molecules per cell, are actually the rarest of any importance. Yet the further one reduces the limit to the number of molecules that can be detected, the greater is the number of elements, particularly heavy metals, that can be found. Any substance active in a quantity of the order of a few thousand molecules per cell would, for example, immediately raise a problem if it formed a stable complex with mercury. Either some strict localization of the mercury, perhaps as a still less dissociated, harmless compound, would be needed or the mercury complex must be as active as the original substance, if not more so. It is therefore not at all improbable that at the dilutions under consideration, a large number of substances have set limits to the structural and functional possibilities of the cell, and that physiological evolution has been determined, albeit negatively, by a far greater variety of metals than the most enthusiastic student of the trace elements would hitherto have deemed possible.

Such a brief vision of the toxicology of evolution is a fitting end to this essay. To go further would merely "spin out our awaking thoughts into the phantasmes of sleep, which often continueth praecogitations; making Cables of Cobwebbes and

Wildernesses of handsome Groves." Nevertheless, turning back to the preceding sentences,

"A large field is yet left unto sharp discerners to enlarge upon this order . . . and moderating the study of names, and meer nomenclature of plants, to erect generalities, disclose unobserved proprieties, not only in the vegetable shop, but the whole volume of nature; affording delightfull Truths, confirmable by sense and ocular Observation, which seems to me the surest path, to trace the Labyrinth of truth." (Sir Thomas Brown, 1658. *Garden of Cyrus V.* 72–73.)

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, 18, Maryland, U. S. A.*

THE GREAT BIOLOGICAL GENERALIZATION

Being a review of *Evolution: The Modern Synthesis*, by Julian Huxley. *New York* and *London* (Harper and Brothers), 1942. Pp. 645. 9¾ x 6¼ inches. $5.00.

By R. F. Kimball, The Johns Hopkins University, Baltimore.

In recent years, quite a number of books on evolution have appeared. In general, these have treated the subject from the point of view of some one biological discipline. Huxley, on the other hand, has undertaken the imposing task of a general synthesis from the point of view of not just one field of biology but of many. In this task, he has succeeded remarkably. It is perhaps not too much to say that this book is one of the outstanding works of its kind.

With such a broad scope, it is obvious that no one aspect can be treated exhaustively even in a book the size of this one. Rather the major principles are discussed and detailed examples particularly pertinent to them are given. Thus the contributions of genetics to evolution, while forming the framework for the whole book, rightfully are given much briefer treatment than in several other works in which these contributions form the main theme. A more detailed treatment is given to recent contributions of systematic and combined systematic and genetic studies to evolution, in particular to the problem of speciation. One of the welcome features of the book is the treatment of long range evolutionary trends, a subject which has tended to be lost to view in the recent preoccupation with genetic studies and the speciation problem. Thus a broad picture of evolution is given starting with basic genetic mechanisms, proceeding through short range changes leading to speciation and adaptation, and ending with long range changes leading on the one hand to specialization and on the other to general progress.

The book is definitely written for the professional biologist. However, Huxley states in his preface that he hopes it may prove of value to the layman who is equipped with some knowledge of biology, particularly of Mendelian principles. There is much in the book, especially in the latter part, that should be of interest to the layman, though unless his knowledge of genetics is good he will undoubtedly find certain parts difficult. Huxley's clear and interesting style should aid him considerably. Nevertheless, the book is really a technical work for biologists interested in evolution. For them it is essential reading.

It would be impossible to write a book of this magnitude on such an actively growing subject without expressing views which will not meet universal approval. Huxley's treatment is in general very fair and well rounded. However, he is not always as critical as might be desired. For example, the interpretation placed on certain cases of adaptation seem based on much too little evidence.

The book has no figures and only a few charts. In general, this lack is unimportant but in some cases figures or diagrams would have added considerably to the clarity of presentation. The lack of maps in the chapter on geographical speciation is particularly unfortunate.

There is an extensive bibliography and three indexes, "Subjects", "Organisms", and "Authorities".

The basic theoretical framework around which Huxley has written is Darwinism as modified in recent years by the findings of genetics. The first chapter gives a semi-historical account of Darwinism, including its eclipse in the early part of this century and its rebirth more recently. Various criticisms that have been leveled at Darwin's theories are discussed. It is pointed out that most of these criticisms relate to Darwin's lack of information concerning the nature of variation and that they have disappeared as a result of increased knowledge of genetics. The fundamental principles on which the remainder of the discussion rests are thus established.

The second chapter is likewise an introductory one.

In it the logical principles on which the treatment of evolution must be based are critically discussed. The chapter title, "The multiformity of evolution" indicates the viewpoint which Huxley takes here and throughout the book. Evolution is a complex, many sided subject. No one approach, no one type of organism is sufficient to give an overall picture. For example, he points out that data from paleontology cannot logically give decisive evidence for the method of evolution. Such data can only tell us whether methods of evolution proposed by students of other disciplines do or do not fit the facts of paleontology. Huxley does not mince words in pointing out the errors in logic which have arisen as a result of failure to realize what conclusions are justified on the basis of particular types of data.

The third chapter discusses the Mendelian basis for evolution. Huxley's treatment is not detailed and assumes a good deal of knowledge on the reader's part. Rather he stresses certain aspects which are of particular importance for the general synthesis. He lays particular stress on R. A. Fisher's concept of the gene-complex, and the adjustment of each gene by selection of modifiers so that it forms a part of an harmoniously working whole. This idea of harmoniously adjusted gene-complexes forms an important part of the discussion in later chapters. A quotation will show the rôle Huxley considers it to play in evolution.

> Ten years ago evolutionary change, on the neo-mendelian view, depended on the co-operation of two processes only—the presentation of ready-made building-blocks by mutation, and the utilization of certain of them under the influence of selection. To-day we have been brought to realize that a third process is at work—change, primarily recombinational, in the residual variability of the gene-complex; and this can shape the building-blocks so as to enable them to fit in better with their neighbors and with the general plan of the building.

While the concept of the adjustment of the genome is by no means new with Huxley, he makes a valuable contribution in stressing its importance for the general synthesis.

The fourth chapter entitled "Genetic systems and evolution" discusses the evolutionary origin and adjustment of the various parts of the genetic system and the influence which various types of chromosomal and breeding systems may be expected to have on evolution. The writing of this chapter has been much influenced by Darlington's book *The Evolution of Genetic Systems* and Darlington's ideas on chromosome behavior in general.

The problems involved in speciation are treated at considerable length in the next three chapters. The first of these deals primarily with geographical speciation, the second with ecological and genetic speciation, and the third summarizes the relation of the discussions on the other two to general problems of evolution and systematics. Huxley emphasizes that there is no single method of speciation and so no single kind of species. As a consequence, he rejects definitions of species which are based on single criteria whether they be morphological differences or failure to interbreed in nature. He points out that in actual systematic practice the purely pragmatic needs of "pigeonholing" different groups must be taken into account. After considerable discussion he reaches a definition of the species which can be given in his own words as follows:

> In most cases a species can thus be regarded as a geographically definable group, whose members actually interbreed or are potentially capable of interbreeding in nature, which normally in nature does not interbreed freely or with full fertility with related groups, and is distinguished from them by constant morphological differences.

Huxley points out that even this rather broad and general definition will meet difficulties in some cases where one or the other criterion breaks down. While this definition is less clear cut than those based on some single attribute, it probably makes a closer approach to the situation actually found in nature; for as Huxley emphasizes, evolution is a manifold process proceeding in different ways in different groups.

Geographical speciation is considered in some detail, emphasis being placed on such phenomena as geographical replacement, clines, and range changes. The rôle of ecological and climatic differences in bringing about adaptational differences in groups separated primarily by geographical factors is discussed. At the end of the chapter a very good summary of the various factors involved in geographical differentiation is given.

When geographical isolation is a primary factor in separating and keeping groups apart, they may be expected to have more or less continuous ranges. On the other hand, when ecological factors are of primary importance, quite discontinuous distribution might be anticipated. Huxley discusses in some detail the problems involved in these latter cases. He points out that a number of examples, in which ecological isolation is apparently the primary factor in isolation, may be really the result of geographic isolation with adaptation to different conditions followed by range changes resulting in the intermingling of the groups. However, he apparently believes that many are actually cases of differentiation *in situ* with ecological barriers serving as the primary isolating mechanism. A fuller treatment of this problem than Huxley gives might be desirable since the evidence on the matter seems to be far from clear.

Abrupt separation of groups as a result of changes in the genetic mechanism are treated in some detail. Chromosome aberrations are given a rather brief discussion, but polyploidy, particularly allopolyploidy as a result of hybridization, is considered at some length. When hybridization and allopolyploidy are combined with various types of asexual reproduction in plants a

complicated "reticulate" type of evolution results in which the delimitation of species becomes a more or less arbitrary matter. Huxley points out that a reticulate type of evolution has also been at work in recent times in man though at a lower taxonomic level and as a result of different conditions.

Thus speciation is a complex and varied phenomenon differing from group to group. Some of the variability arising during speciation will lead to the production of types with higher all-round efficiency, or to new specializations, but much of it Huxley believes is "a mere frill of variety superimposed upon its [evolution's] broad pattern."

Systematic classification has often been considered to be based, ideally at least, on phylogenetic relationship. Especially has this ideal been held by students of evolution. Thus it is rather surprising to find that Huxley attempts to get away from this point of view. As a matter of fact he makes a very good case for the conclusion that the aim of classification should be to describe as accurately as possible the existing diversity of organisms. He points out that while in higher categories phylogenetic relationships may often be established this is difficult and frequently impossible in lower categories. However, a description of existing diversity may result in an approach to a phylogenetic classification, but this should not be the primary aim. In order to adequately meet the needs imposed by recent advances in the study of systematics, some additions to the recognized categories at the specific and subspecific levels may have to be made. For example, in some cases clines should be considered as units warranting names subject to the international rules of nomenclature. In addition various subsidiary nomenclatures not subject to these rules should be employed for special purposes. Thus Huxley calls for a change in emphasis from an ideal phylogenetic scheme of classification to one based on a practical description of the diversity that exists at the present time with a broadening in the scheme of classification to meet the complexity which actually exists.

One of the most discussed corollaries of evolution, often one of the most poorly discussed, is adaptation. The subject is a difficult one, for carefully carried out experiments are all too infrequent while superficial observations are numerous. Some of the examples Huxley gives appear to have been investigated only superficially, and he is not always as cautious as might be desired in drawing conclusions concerning them. However, the chapter is excellently planned and presents a well thought out picture of the subject. The attempts of various biologists to deny the reality of adaptations are shown to be based on faulty reasoning. Natural selection is accepted as the explanation for the origin of adaptations while Lamarkism and orthogenesis are shown to be either incapable of interpreting the facts or unnecessary. The important point is made that adaptation and selection are not necessarily beneficial in the long run to the species as a whole. Intragroup selection in particular may lead to results which will finally end in extinction. Huxley ventures into the perhaps dangerous but important field of application to human social problems by pointing out that this leads to the conclusion that competition and its results are not necessarily beneficial to man.

Not only is natural selection not the instrument of a God's sublime purpose; it is not even the best mechanism for achieving evolutionary progress. An important step towards a rational applied biology will be the full analysis of the various modes of operation of selection with a view to its eventual control and its intensification for our own purposes.

Most of the book is concerned with what might be called minor evolutionary changes. However, in the last two chapters Huxley deals with the less understood subject of major evolutionary trends leading on the one hand to specialization and on the other to general progress. In the first of the two chapters, trends leading toward specialization are considered. Adaptive radiation is discussed in some detail along with its explanation on the basis of natural selection. Apparent orthogenetic trends are dealt with, and it is pointed out that these can in general be explained on the basis of selection. Despite this, Huxley apparently believes that there are certain non-adaptive trends in which "we must provisionally face an explanation in terms of orthogenesis—i.e. of evolution predetermined to proceed within certain narrow limits, irrespective of selective disadvantage except where this leads to total extinction". However, the examples which he cites seem very inconclusive since they are groups which are known only from paleontological evidence and the possible adaptive significance of the trends they exhibit are very difficult if not impossible to ascertain.

This chapter also considers various restrictions on variability imposed by the past history of the group and by its biological peculiarities. The consequence for evolution of "differential development" with special emphasis on the rate concept of gene action are discussed in some detail. The importance of allometric growth as an explanation of certain orthogenetic trends is pointed out. Huxley has done an important service in this treatment of major evolutionary trends, for they have all too frequently been completely overshadowed by the emphasis in recent years on specific and subspecific evolution.

In the final chapter, Huxley deals with evolutionary progress. He takes issue with those who would say that such terms as "progress", "higher", and "lower" have no scientific meaning and ably argues that such a standpoint is based on illogical thinking. Evolutionary progress is a reality, and by surveying the facts concerning dominant groups it can be concluded that it involves advances in control of the environment and in independence of the environment. A consideration of the

mechanism of progress and a brief outline of the course of evolutionary progress are given.

Perhaps the most interesting, if also the most debatable, part of this chapter is that in which he attempts to look into the future. He believes that in the progress of the human race subjective human values as well as objective biological values play a rôle. Furthermore, there are certain restrictions on the type of progress imposed by man's biological peculiarities. For example it is unlikely that the species will break up into separate radiating lines of adaptation. Certain possibilities for genetic change in the future are cited. For example, Huxley speaks of letting "the mammal die within us, so as the more effectually to permit the man to live." However, perhaps the most important conclusion for Huxley is man's uniqueness in evolutionary history and the necessity of clearly facing the consequences of this if future progress is to be made. "Before progress can begin to be rapid, man must cease being afraid of his uniqueness, and must not continue to put off the responsibilities that are really his on to the shoulders of mythical gods or metaphysical absolutes". It might have been added that man must also squarely face the results of the fact that he is in many ways not unique, for this may have equally important consequences for his future evolution.

This discussion of the future is undoubtedly subject to considerable criticism as a result of differences of opinion. Nevertheless, Huxley is to be commended for his intellectual bravery in undertaking it and for his interesting, thought provoking treatment. If man is ever to have any real control of his destiny such discussions as this are essential.

BRIEF NOTICES

EVOLUTION

MAN IN EVOLUTION.

By G. de Purucker. Theosophical University Press, Point Loma, Calif. $2.50. 8 x 5¼; x +389; 1941.

If the author of this book had maintained throughout the high standard which he set in the opening chapters he might have produced one of the significant anthropological works of the twentieth century; as it is, the remainder of the work is largely anticlimax. The best way to appraise its value is to note that the author believes man to have originated in the Jurassic period, that he is the primitive mammal from which even *Ornithorhyncus* is descended, and to which he is more closely related than to the anthropoid apes, and that the theory formulated by Darwin is not evolution.

But to the present reviewer even these bizarre idiosyncrasies do not dim the brilliance of the first three chapters, in which the inter-relations of science, philosophy, and religion are expounded with both clarity and charity. According to the author,

> religion comprises the mystical and devotional (but not the emotional) faculties of man. Philosophy gathers together and formulates in intellectual fashion the truths which the consciousness . . . obtains from nature . . . third is the operation of the human mind which classifies . . . the facts of the beings surrounding us, which it studies; and that is science.

The author then points out that these three fundamental operations of consciousness cannot be separated. They do not occupy thought-tight compartments in the mind, but interact upon one another, being as inseparable as the three sides of a triangle. Truth must satisfy the entire nature of man, and the validity of any belief that does not do so is seriously open to suspicion. The conflict between religion and science (as well as the less conspicuous but more fundamental conflict between science and philosophy) is an indication that something is lacking in the mental process of the thinker, for in actuality no antinomy can occur among these three. This is an essentially sane basis on which to build a philosophy of mental life, and while we regret that the structure which the author has chosen to erect upon it is so disappointing we must admit that the foundation is sound.

The author makes a telling point when he observes that just as there is no royal road to learning, neither should there be any aristocracy of erudition. Education should be made readily available to all those who are capable of benefitting by it. But the author also points out (and this reviewer agrees with him) that in the United States we tend to overdo the principle of democracy in education. Our universities are surcharged with a large student body which is exposed to education, but somehow the education does not take. We need only contemplate the sad state of the world around us today which has been brought about by well-meaning and liberally educated people who are completely incompetent to assume the moral responsibility involved. We have committed ourselves to the policy of the acquisition and dissemination of knowledge, even among those who lack the wisdom to use it well. How sadly true is the poet's statement that "a little learning is a dangerous thing!"

This is an enigmatic book. Its contribution to scientific thought is negligible, but considered as a philosophical treatise the first few chapters are profound. The author deserves to be commended for the purity of his diction and his self-restraint in criticizing those with whom he disagrees.

TRANSACTIONS OF THE AMERICAN PHILOSOPHICAL SOCIETY. *New Series, Volume XXXII, Part III.*

Papers as follows: *Research on Early Man in Burma*, by Hellmut de Terra and Hallam L. Movius, Jr.; Supplementary Reports upon the *Pleistocene Vertebrates and Mollusks of the Region*, by Edwin H. Colbert and J. Bequaert; and *Pleistocene Geology and Early Man in Java*, by Hellmut de Terra.

The American Philosophical Society, Philadelphia. $3.00. 11¾ x 9¼; 265–464 + 35 plates; 1943 (paper).

This publication embodies results of the American Southeast Asiatic Expedition for Early Man of 1937–38. The expedition was designed primarily to fill the gap in the stratigraphical and archeological data relating to fossil man in Asia—a gap that existed between India and China on the one hand and between India and Java on the other. Burma, being intermediate, was selected for special study.

Nearly the whole of this report is devoted to Burma. The leader of the expedition, de Terra, deals with its Pleistocene geology, Movius with the stone age implements, Colbert with Pleistocene vertebrates, and Bequaert with fresh-water shells. There also is a section by de Terra devoted to the Pleistocene geology of Java as related to fossil man of that region.

LIFE THROUGH THE AGES. *A Chart.*

By William Gordon Huff and Ray Stanford Strong. Stanford University Press, Stanford University, California. 50 cents. 25 x 19; 1; 1943 (paper).

This interesting chart presents, in picture form, the origin of life and the probable evolution of animal forms through all the important eras of the world's history from the Archeozoic to recent times. While the method of presentation here is unique, the "missing links" are still conspicuous—in this case particularly, since they are represented by fade-outs and broken lines in the "tree" of evolution.

The chart will make an excellent wall or bulletin-board decoration for the biology classroom if it does not lose its color too quickly.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 47, No. 5. The Pleistocene Birds of San Josecito Cavern, Mexico*, by Loye Miller.

University of California Press, Berkeley. 35 cents. 10¼ x 6¾; 25; 1943 (paper).

GENETICS

THE GENETICS OF THE MOUSE.

By Hans Grüneberg. Cambridge, at the University Press; The Macmillan Company, New York. $7.00. 8¾ x 5½; xii + 412; 1943.

If one wanted to paraphrase the semitruth of the one time (private!) statement of a leading geneticist, "If you want to study the genetics of the rabbit, learn about rabbits, but if you want to study Genetics, go to *Drosophila*", one could say, "If you want to study human inheritance learn about the genetics of the mouse". Clearly, the morphological and physiological similarities of men and mice suggest direct application to man of the knowledge gained in the experimental mammal of the development of hereditary abnormalities and of the inherited variations within the normal range. The impressiveness of this monograph on the genetics of the mouse is not least due to the fact that the author has had extensive general biological as well as medical training, leading to doctor's degrees in both fields. In concise fashion he has assembled and critically organized the vast material on mouse genetics which is distributed over the literature of genetics, anatomy, pathology, mammalogy, experimental zoology and other fields (the bibliography lists 1141 titles). For each character the information is given as to origin, genetics, description, and, if known, embryology. In general, the latter two items are treated most fully. Thus, unlike *Drosophila*, where an inherited character is best known as a symbol to be used in abstract deductions, in the mouse the character itself in all its phenotypical and developmental aspects occupies the center of interest.

He who thinks of mouse genetics mostly in terms of the classical studies or color genes will be surprised to see that only some forty pages are given to this work while more than two hundred pages are devoted to topics such as endocrine organs, brain, blood, skeleton, alimentary and urogenital systems, serology, and resistance to infectious diseases. An appendix by C. C. Little and P. A. Gorer on The genetics of cancer in mice adds to the value of the book. The author can be congratulated for having made a valuable contribution to biology, basic and applied.

HEREDITY AND ENVIRONMENT. *A Critical Survey of Recently Published Material on Twins and Foster Children. A Report Prepared for the Committee on Social Adjustment. Bulletin 47.*

By R. S. Woodworth. Social Science Research Council, New York. 90 cents. 9 x 6; x +95; 1941 (paper).

The relative contributions of heredity and environment to the total intellectual and social capacity of an individual have long perplexed the scientific investigator and frustrated his many ingenious attempts to clarify the problem. The present study, after much delineation of carefully planned and executed experimentation, leaves us in about the same state of enlightenment which we attained some twenty years ago, i.e. the problem is a grossly complex one; that sometimes heredity and sometimes environment seems to exert the greater influence on the personality; and that the two are so intricately tied together in the individual's experience

that they can probably never be completely isolated and measured.

The state of clarification of the problem is illustrated by the statements in the following quotation: "... (1) that differences in environment can produce substantial differences in intelligence, and (2) that the differences actually present in a community are not due mostly to differences in environment...."—which statements, the author explains most carefully, are not mutually contradictory. The writer admits that the body of data for both the twin studies and the foster parent studies is still too small to warrant any certain conclusions.

The study is concluded with a plea for greater numbers in the experimental groups; improvement of the inadequacies of the tests for mental abilities; and a clarification of the vagueness associated with the measurements of environmental factors.

GENERAL BIOLOGY

JOHN RAY, NATURALIST: *His Life and Works.* *By Charles E. Raven. Cambridge: at the University Press.* 30s. net. 9 x 6; xix + 502; 1942.

Cannon Raven's name on the title page of any book is a sufficient guaranty of its excellence, and his recent lecture tour of the United States is likely to make many wish to read this biography of the greatest biological genius of the seventeenth century.

Unfortunately, little is known about the life of John Ray. It does not offer opportunity for romantic or dramatic presentation. Consequently, in a book devoted to his life and works the emphasis must be put upon the works. For the greater part, the biography is an extremely detailed and highly technical analysis of Ray's writings with ample references to his predecessors who influenced him and his successors who learned from him, with a great deal about his contemporaries with whom he studied, corresponded, and travelled. Chief among these was Francis Willughby, with whom he became acquainted during their college days at Cambridge. It is given to but few to enjoy such a friendship as this, which lasted for eighteen years, and was terminated only by Willughby's sudden death.

Ray and Willughby had dreamed of compiling a natural history of both plants and animals, an ambition which had it reached fruition would have anticipated Linnaeus by upwards of a century. Willughby was to cover the animal kingdom and Ray the plants, but when the former died leaving his *magnum opus* unfinished, his "relict" requested Ray to undertake the entire task, which the latter was only too happy to do as a memorial testimonial to his friend. But Willughby's records were an inchoate mass of undigested data, whose only merit was their comprehensiveness, and Ray was compelled to rewrite practically the entire work. The material was Willughby's but the arrangement and literary composition were Ray's. The work was published as a posthumous writing of Willughby, but according to Canon Raven, Ray would have been justified in calling it his own. He was far more than an editor, and the production was a labor of love.

The first volume of the natural history to appear was the *Ornithology*. With the exception of a work by Belon in the preceding century this was the first book ever written devoted exclusively to birds. The value of Belon's book may be gauged by the fact that he included the bats! Other writers had discussed birds in works of general natural history, but most of these gave the same serious attention to the Griffin, the Harpy, and the Phoenix as to the legitimate birds. Ray's work also included an appendix devoted to fabulous birds but these were merely exotic forms of whose existence he was inclined to be doubtful, having never seen them. Among these listed birds are some species which have since been authenticated, such as the Quetzal, the Condor, and the Hoatzin. For their description Ray was dependent upon Hernandez who had been sent to America by Philip the Second to gather scientific material more than half a century before Ray was born. In the *Ornithology* Ray ventures the opinion that the absence of swallows in the wintertime may be due to their having migrated to a more congenial climate, a thought that must have seemed revolutionary in an age when it was seriously debated by scientific circles whether they hibernated beneath ponds as frogs do, or whether they flew to the moon. He also rejected the popular notion that barnacle geese originated from goose barnacles—a belief that was reprinted during Ray's lifetime by John Gerard, who thought that barnacles were plants, which accounted for the use of these geese as food during Lent, since they were metamorphosed fish!

Mention of fish brings us naturally to consider Ray's work on *Ichthyology*, which was less satisfactory. Willughby's data were so very skimpy that it was necessary for Ray to patronize most of the fishmongers' stalls in the British Isles to obtain study material. He even dissected fish which had been salted and dried. The explanation of his inclusion of the Cetacea is not that he was ignorant of their nature, for he tells us they are homothermal and viviparous, and that they suckle their young. Rather it is because the view was prevalent at the time that the fish are an ecologic and not a taxonomic group. Even today we use the terms shellfish, starfish, and jellyfish—heritages from the time when the "whales and all that move in the waters" were considered fish.

Ray was of course no evolutionist. Had he lived two centuries either earlier or later he would have been, but in his day the intellectual world was dominated by Jesuitic scholasticism with its belief in the permanence of types. Organisms might be grouped together on the basis of resemblances, but there was no real relationship

among them. The best classification was the simplest, because it was the most convenient. The experiments of Redi had been performed but had not met with universal approval; in accepting them and rejecting the doctrine of abiogenesis Ray came about as close to evolution as was possible.

Willughby left no notes on the mammals, reptiles, or amphibians, and here it was necessary for Ray to break new ground. What had been previously written was widely scattered through many diverse authors, such as the naturalists Gesner and Aldrovandus and the laboratory scientists Malpighi and Swammerdam. To the observations of these he adds so many of his own that Cuvier declared him to be the founder of comparative anatomy. Ray published nothing on the invertebrates. The Mollusca and the Crustacea had been ably covered by his friend Martin Lister. This left only the insects—an elastic term which included all other animals. When Ray died in 1705 at the age of 78 he left an unfinished manuscript which he had been working on for about ten years.

But Ray's principal contribution to science was not in the field of zoology but botany. It was less spectacular, however, for in his day botany was already an established science. The use of plants in pharmacology and horticulture had made accurate botanical knowledge indispensible, and the strange mixture of mythology and truth that clouded the zoological sciences and was a hangover from the dark ages had long since been dissipated in botany. Ray's botany differs from that of his predecessors chiefly in being bigger and better; he progressed farther along the paths which they had already opened. But in zoology he had to break his own way through an uncharted wilderness—he was not only pioneer but also pathfinder. The same was true of his palaeontology; he was one of the first to realize that fossils are organic remains and not the work of a capricious nature trying to mystify the human intellect.

Lack of space precludes detailed mention of Ray's *Collection of English Words*, a venture in scientific philology. But it would be highly inappropriate to pass over the crowning achievement of his career, *The Wisdom of God*, to which the author devotes his closing chapter. Beginning as a modest volume of 249 pages, it went through four editions during Ray's lifetime, doubling its size. Its last edition appeared as late as 1827. It is practically a complete compendium of all scientific and philosophical knowledge of his day, and few works have had greater influence on subsequent thought. The debt which such diverse writers as Joseph Butler, John Wesley, Charles Darwin, and even Hans Driesch and Joseph LeConte owe it is incalculable, and without it Paley's *Natural Philosophy* and Bergson's *Creative Evolution* would have been impossible. The revolt against the mechanization of humanity, the love of nature and desire to understand her which characterizes the modern Anglo-Saxon race stem largely from this work, which as Canon Raven aptly concludes, is Ray's proper memorial.

BIOLOGY: THE SCIENCE OF LIFE.

By Mary Stuart MacDougall in Collaboration with Robert Hegner. McGraw-Hill Book Company, New York and London. $4.00. 9 x 5¾; x + 963; 1943.

Numerous college texts in general biology have appeared in recent years, differing in comprehensiveness, point of view, and organization. This is the longest and most comprehensive which the reviewer has yet seen. The zoological section alone is as complete as most textbooks in general zoology.

The point of view is expressed by the author in the preface where she states, "A general course in biology should emphasize human biology." The relationships of other organisms to man and the biology of man himself are thus given considerable emphasis. Moreover, the interrelationships of all organisms are brought out by the comparative treatment of both anatomical and physiological problems. Further clarification is achieved through the medium of diagrams.

The organization of the various topics is somewhat unusual. General subjects such as the nature of biology, the cell, tissues, ecology, and classification are placed in an introductory section. This is followed by a brief and perhaps over-simplified treatment of plant biology. Here a common error is perpetrated: that of presenting plant anatomy as a two-dimensional phenomenon. Some of the illustrations, notably Figs. 63, 73, and 76A, are apt to be more confusing than helpful to the elementary student because they are on too small a scale and details are blurred.

The zoological section is extensive and as abundant in detail as the botanical section is wanting. It is introduced by a discussion of the frog as a typical vertebrate. This is followed by a comparative treatment of the animal kingdom, beginning with the protozoa.

Although the physiology of type organisms is given some space in the botanical and zoological sections, general physiological principles are discussed in detail in a separate subdivision under the title "General biology." Topics such as foods, nutrition, circulation, respiration, excretion, etc. are included. Both animal and plant processes are discussed under each heading, again from a comparative point of view. Thus, the botanical material presented in the book as a whole is considerably greater than that contained in the special section on plant biology.

The last three sections of the book are relatively shorter, but they add much to a basic knowledge of biological principles. They deal with heredity and organic evolution, applied biology, and the history of biology.

In spite of some errors—which are lacking in very

few books—the wealth of material, illustrations, questions, and references contained in the present volume will doubtless make it popular as a text. It should be particularly useful for a comprehensive year's course in biology.

PAPERS FROM TORTUGAS LABORATORY, VOLUME XXXIII. *Carnegie Institution of Washington Publication 524.*

Carnegie Institution of Washington, Washington, D. C. $1.50 (paper); $2.00 (cloth). 9⅞ x 6⅞; iii + 195 + 7 plates + 1 folding map; 1942.

This volume of collected papers from the Tortugas Laboratory contains several articles of major interest. Two of these are concerned with the swarming of the Atlantic palolo worm. By extensive observation the investigators (Clark and Hess) found that the worms are not necessarily restricted in their period of swarming, but may do so at any phase of the lunar cycle except near the time of the new moon. Major swarms, however, occur within five days of a quarter moon phase. Other environmental influences besides the lunar cycle are shown to affect this periodic phenomenon. If the wind velocity is over 8 miles per hour causing wave action and turbulence, swarming does not occur unless the reef is protected. This explains why, in some areas, swarming may take place while it fails to do so in other localities. Experimental oxygen determinations showed that as the worms matured, the region of highest respiratory activity changed from the anterior end of the worm to the posterior end of the epitoke. These observations agree with the well-known facts that the epitoke breaks off and swims hind end foremost to the surface.

In the second paper the same investigators found experimentally that the immature worms and the atokal portions of the mature worms were negative to light of intensities above 0.01 foot candles. At full moon (0.02 foot candles) the worms hide from the light in their burrows, but at the quarter moon (0.002 f.c.) they are able to cast off the free-swimming epitokes which are photopositive to the highest of moonlight intensities.

The longest contribution in the volume deals with the plant ecology of the sand keys west of Key West. These keys were built up by the constructive accumulation of detritus by marine currents. Vegetation became established and the topography of the islands was thus maintained. The two distinctive types of vegetation present are the mangrove swamps and the sand-strand community, the former originating on fine-particled sedimentation, usually flooded by the tide, the latter on coarse sands above high tide. Succession leads to a hammock forest. The types of plants involved, their reactions and adaptations, dispersal, populations, etc., are discussed in the first part of the report. The second part describes the islands in detail, with maps of all the keys included.

The three remaining papers are brief taxonomic notices on trematodes and ciliates from the Tortugas.

HUMAN BIOLOGY

A HISTORY OF THE CANADIAN PEOPLE. *Volume I: New France.*

By Morden H. Long, with illustrations by C. W. Jefferys. The Ryerson Press, Toronto. $3.50. 9 x 6; xiv + 376; 1942.

Although Canada and the United States have much in common, including the world's longest unfortified international boundary, the development of the two countries has been widely different. This is due partly to a difference in their natural resources, but chiefly to a difference in the type of their respective settlers.

Let us consider the resources first, as the simpler factor. The wealth of the United States was in its forests and agriculture; its settlers were largely farmers who cleared the ground and sowed their crops. Each settler owned his own home and worked his own plot of ground, asking nothing of his neighbors but to be let alone. The economic system was competitive which caused the failure of many agricultural enterprises, but land was cheap; the bankrupt farmer needed only to give the Indians sufficient fire water, and perhaps shoot a few of them, to enable him to push the frontier a few miles further westward and then start again from scratch. After dispossessing the Indians he had no further use for them.

But the wealth of Canada was in its furs. To succeed in the fur industry it was necessary to make friends with the Indians. Trappers can not work in large numbers, they must operate singly. It was not to their interest to establish a frontier, for this would have driven the wild game deeper into the inaccessible reaches of the continent and added to the dangers as well as the difficulty of following a trap line. They did not clear the land nor did they own it, but left the Indian in undisputed possession, and they opposed every attempt of the French Government to send colonizers. When the English colonies could boast a population of over a million there were only about two thousand individuals in Canada, practically all of whom were confined to the manorial estates about Quebec. This condition eventually led to the conquest, for when Quebec fell Canada fell—there was no other Canada.

The first permanent settlement by the English in the Western Hemisphere was established at Jamestown by Captain John Smith in 1607. The first by the French was established at Quebec by Champlain in 1608. But there was far more than one year's difference between English and French civilization in the Old World. For over two centuries the tide of feudalism

in England had been receding. Although two abortive attempts were made by the English to establish the feudal system in America (as the old manorial estates in the valleys of the Hudson and the James bear witness) the spirit of democracy was in the air, and every man in British America considered himself the equal of any other man. Even England itself essayed the republican form of government for a brief period under the Cromwells.

But in France feudalism was just reaching the climax of its fruition and it was unthinkable that any other form of social organization should be tried in Canada. Large tracts of unsurveyed ground were awarded by crown grant to the impoverished members of the nobility in a vain effort to help them recuperate their fortunes. They were supposed to settle feudal retainers on these tracts, and many of them did so. Perhaps the best known of the feudal institutions of this period surviving today are the community bake ovens that border the highway between Quebec and Ste. Anne de Beaupré.

To have settled retainers on a large scale, however, would have been to destroy the most promising source of potential wealth. Consequently some of these landed proprietors made no effort at all to colonize their holdings, but instead waited idly for the unearned increment which they hoped might accrue to their property from the improvements installed by their neighbors.

Another striking difference between the English and French colonists was in their religious motives. At one time five of the thirteen English colonies were controlled by religious and political refugees who came not only from England but from continental Europe as well. In two other colonies the balance of power was held by persecuted minorities. But Canada during the French period was always closed to this sort of immigration. Even France's single Protestant king, Henry of Navarre, failed to provide a haven for the Huguenots in Canada, and eventually they settled in South Carolina. Had they been admitted to Canada, the Tricolor might be waving over the citadel of Quebec today. The only settlers in Canada to be actuated by religious motives were the members of the Jesuit order, and these came not to seek religious freedom but to perpetuate in the New World the established church of the Old. The persecutions that occupy such a large place in Jesuit history were still more than a century in the future.

The subsequent outcome of the difference between these two attempts at empire building was a foregone conclusion. The English colonies were settled by a heterogeneous assemblage of Europeans whose chief common trait was the habit of thinking for themselves—a habit acquired in the hard school of experience. It was inevitable that sooner or later they would declare themselves independent of the old country. The Stamp Act was the occasion for, but not the cause of, the Revolutionary war. But the French colonists were nationally and intellectually a homogeneous group. They were unable to stimulate each other to original thought, with the result that their decisions were all made at the French court. They were not revolutionaries and had no desire for independence as Montgomery was to learn in 1775 and Hull in 1812. When Wolfe and Montcalm met on the plains of Abraham the French were united to a man, but they lacked power, and the peculiar anomaly that is the fate of Quebec today arose—its citizens are politically English but culturally French.

Within a generation the monarchy had collapsed. Political changes followed each other in kaleidoscopic succession. But Canada was outside the empire and was unaffected by these changes. Today, if a follower of *le Grand Monarque* could return to the earth he might feel more at home in Quebec than in Paris.

The author of this story of the people of Canada teaches history in the University of Alberta. So far there has appeared only the first volume which brings the story to the fall of Quebec. If the subsequent volumes prove to be as well conceived and constructed as the first the work is likely to become a classic. It is well provided with illustrations and reproductions of historic maps, but the latter are more effective in illustrating contemporary ideas of Canadian geography than in showing the trails of the pathfinders. A modern map showing the trails of these would have been a helpful addition. For instance, it is impossible to follow the journey of Etienne Brulé or of Pierre la Verendrye from the data in the text. The former of these served under Champlain, penetrating as far westward as Lake St. Clair, returning to Quebec by way of the Ohio valley and Chesapeake Bay, while the latter led an expedition to the Black Hills, and possibly the Big Horn mountains in the thirties of the eighteenth century. No one subsequently penetrated so far west until Mackenzie reached the Pacific sixty years later.

It was on this expedition that Verendrye encountered some Indians riding horses which they had obtained in Mexico—the Indians of the plains had no horses. It was also then that he discovered the famous Verendrye stone, which was probably a Norse runestone, but which Verendrye thought to be of Tartaric origin. Nothing so much as this indicates his vague notions of distance—he had little idea of the breadth of the American continent, and none at all of that of the Pacific ocean. For all he knew there might be a land connection between America and Asia, thus making the journey from Tartary to Dakota an easy and natural one. In fact, the discovery seemed of so little importance to him that he never mentioned it in any of his records, and we know the story only because he related it to Peter Kalm who incorporated it in his diary. The present author has also omitted it, but he has given us a thrilling story without it, which the lover of adventure and romance will enjoy as much as the student of history.

SOUTH OF THE CONGO.

By Selwyn James. Random House, Inc., New York. $3.00. 8¾ x 5⅝; 347; 1943.

Today, the Cape of Good Hope at the southern tip of the continent of Africa has resumed its old strategic importance. It commands the shipping route to the Far East and India, in preference to the more precarious route through the Suez Canal, and, in addition, the route of the many convoys carrying military aid and supplies from the United States to the Soviet Union.

As early as 1487, when the Cape was discovered by the Portuguese, this port provided a fine natural harbor, fresh water, and food to the mariners for their journey into the fabulous East. About 165 years later the Dutch took over the Cape and Portugal's trade dwindled to near nothing. Still later, England took it over and her trade with the Orient became of prime importance. Through those years it was only necessary to occupy a few coastal regions in order to hold this key point. But since then, with the country becoming overrun by expanding colonists, the nation holding the Cape must be on the alert against enemies from the interior. To date Southern Africa has thwarted all attempts of the Axis to gain any permanent footing. But the Axis has filtered into the country and government, weakening the Union of South Africa's war effort, and may yet start a civil war to unseat the anti-Nazi statesmen.

Looking at a map of Southern Africa, the following territories are observed. Belgian Congo, Tanganyika, Mozambique, Madagascar, Northern and Southern Rhodesia, Angola, South West Africa, Bechuanaland, Swajiland, Borsutoland, and the Union of South Africa.

These, then, are the territories with which this book is concerned. Only incidentally are they studied as geographical units; the major emphasis is on their strategical and political importance to the cause of the United Nations. Economically, too, the stakes for which the warring powers are gambling here are equally great because Africa is rich, probably the richest undeveloped continent in the world. So far, however, it has been largely neglected. Huge quantities of key materials lie unexploited. The whites of Southern Africa have scarcely begun to scratch the surface of its wealth. Diamonds, gold, iron, tin, copper, manganese, vanadium, asbestos—these are some of the minerals in Africa's earth. With the possible exception of gold, they are produced in relatively small quantities. The Nazis lose no opportunity to describe how they intend to exploit Africa's resources to the limit if they ever lay hands on that continent.

In this book the author has expertly observed and sincerely related from his personal association with the blacks and whites the great conflict going on in this vast country. This is a fine history, brought up to date, of the country south of the Congo—a place to keep in mind these days.

ARCHAEOLOGICAL RESEARCHES IN THE NORTHERN GREAT BASIN. *Carnegie Institution of Washington Publication 538.*

By L. S. Cressman. Carnegie Institution of Washington, D. C. $4.00 (cloth); $3.00 (paper). 11½ x 9; xvii + 158 + 102 figures; 1942.

The Northern Great Basin in Southern Oregon forms part of that Western area where probable association of man with extinct (early Recent) fauna witnesses considerable antiquity of man. The culture, described in this book and excavated from caves located on the fringe of lake beds now desiccated, is of course more recent. The book is mainly occupied with the problem of the temporal and cultural relationship of this Oregon cave material to the Basketmaker culture of the Southwest. Cressmann tries even an absolute dating of the deposits as they are interrupted by a layer of pumice supposed to be the result of an eruption 5,000 years back.

The book opens with chapters on geological considerations, climatic character and life zones and descriptions of the sites of the six caves. Cressman then examines in detail the objects found, especially the typical basketry, sandals, bone artefacts (L shaped awls), wooden artefacts (atlatls) and stone artefacts. A second part of the book is devoted to the Lower Klamath Lake Region in order to facilitate an examination of the question of continuity with more Southern finds. Special chapters are here contributed by H. P. Hansen on pollen studies of peat profiles in the region, by P. S. Conger on Diatoms and F. C. Baker on Mollusca of the region. R. F. Heizer gives a survey of some Northern Nevada cave excavations.

Cressmann regards the Oregon caves as the seat of a lake marsh culture, enriching itself during an improvement of climatic conditions in the second millenium before the Christian era, and disappearing, with the onset of desiccation, around the beginning of the Christian era. He regards the characteristic twined basketry as of definitely Northern type. He thinks the culture of these caves to be antecedent to that of Lovelock cave and to the Basket Makers who are now also regarded as being of Northern origin, adopting only their agriculture from the South.

While the argumentation of the author generally seems rather convincing and his cautious attitude towards the very few human skeletal remains is praiseworthy, the reviewer would not feel able to draw such far-reaching conclusions from the pumice, as long as the geologists have not made up their minds whether it is 1000 or 25,000 years old. The book deals very ably with one of the most fascinating problems of North American archeology. Its presentation is excellent, poised and clear, and it is splendidly illustrated. There is no index.

THE MAKING OF MODERN NEW GUINEA *with Special Reference to Culture Contact in the Mandated Territory. American Philosophical Society Memoirs, Volume XVIII.*

By Stephen Winsor Reed. American Philosophical Society, Philadelphia. $4.00. 9 x 6; xix + 326; 1943.

The huge island of New Guinea, for a long time of interest only to biologists, prospectors, traders, and missionaries, is most likely to retain the international importance it has acquired with the war. Until recently the aborigines survived at such an unspoiled, neolithic level of culture as has disappeared from most other parts of the world. The impact of modern civilization upon a race of the age of wood and stone is producing a rapid and profound shift in social evolution. This change is the main subject of the present, scholarly report. The author, a sociologist at Yale University, was in New Guinea in 1936 and 1937 to collect material for this volume. The investigation is limited to the Mandated Territory consisting of northeastern New Guinea and the Bismarck Archipelago.

The largest part of the book deals with the administration of the natives. European influence began to exert itself on a small scale and in extremely limited zones in the 16th century, and it was not until late in the 19th century that Germany claimed and administered this territory. British occupation began in 1914. The detailed account of these epochs in the history of white man's rule in New Guinea is followed by a chapter on the economic prospects of the mandate. A final and lengthy chapter is entitled "Modern New Guinea, the genesis of a new society" and discusses the timely problems of supply, composition, and treatment of labor, the development of new caste systems, the influence of missionaries, and particularly the changes in aboriginal cultures. The latter are shown to be less abrupt than in most other cases of culture-clashes following colonization.

Of greatest interest to the biologist is the introductory chapter on The land and the people. This contains chiefly an excellent survey of the aboriginal cultures, as they have been described in other publications by different writers.

The author summarizes his findings aptly and succinctly by stating that the New Guinea native has benefited from modern administration by having gained most of all a greater sense of security and also by being in better health and enjoying a steadier diet. "Whether or not he is a happier individual than his father or grandfather we cannot know."

An Appendix of 24 pages, useful to-day to our armed forces, discusses the Language adjustment: Melanesian pidgin. Another appendix tabulates the census figures from 1921 to 1938. In 1938 the Mandated Territory contained a total of 6300 whites, Chinese and Malays and nearly 600,000 natives, of whom about 42,000 are indentured laborers. A carefully prepared bibliography of several hundred titles constitutes a further valuable contribution.

SOCIAL DEFENSES AGAINST CRIME. *Yearbook. National Probation Association 1942. Current Opinion on the Treatment and Prevention of Delinquency and Crime. Papers Given at the Thirty-sixth Annual Conference of the Association at New Orleans, Louisiana, May 7–15, 1942.*

Edited by Marjorie Bell. National Probation Association, New York. $1.75 (cloth); $1.25 (paper); 9 x 6; 346; 1942.

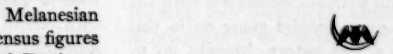
The papers in the 1942 *Yearbook of the National Probation Association* are grouped under the following headings: I. Crime and the community; II. Delinquency in wartime; III. Scope and place of the Juvenile Court; IV. Services for the unadjusted child; V. Individualized treatment for adults; VI. Administration of adult services; VII. Staff training; VIII. Legal -digest. The final chapter gives the reports of the var ous activities of the Association, minutes, officers, by-laws, and program.

In the first group of papers Rosco . Pound, in discussing the rise of socialized criminal justice, speaks of the new attitude that has grown up in dealing with the causes and conditions of juvenile delinquency and of treating individual delinquents. He says:

> To bring it about that judges and probation officers and public school teachers work together efficiently, as together exercising the royal function of *parens patriae*, means that a new spirit has been developed to replace the sharp lines which governed in the English-speaking world until the last two decades. Moreover, it is gratifying to note that the technique and the organized experience of such cooperation have grown from or have sprung up about unofficial voluntary social work. Such a development is characteristically Anglo-American. It is the traditional way of doing things in the English-speaking world. We habitually do things in this way, by voluntary private initiative rather than by official action.

In the same group of papers Walter R. Chivers, in discussing the Negro delinquent, emphasizes the need for slum clearance, improved health, the importance of Negro officers selected by the Negro populace to deal with delinquents, and states that "Negroes must at least be part and parcel of those policy-making bodies whose actions affect their welfare."

All of the 23 papers in the volume are interesting and have much to offer not only to those whose interests fall in this field but also to the general reader.



SOURCE MATERIAL OF THE HISTORY AND ETHNOLOGY OF THE CADDO INDIANS. *Bureau of American Ethnology Bulletin 132.*

By John R. Swanton. Smithsonian Institution, Washington, D. C. 75 cents. 9¼ x 5¾; vii + 332; 1942 (paper).

The group of Indian tribes called "Caddo" has played a conspicuous rôle in the early history of the Southwest. Caddo pottery is of particular fame and a Caddo word was even to become the name of the largest state of the Union (Texas). But this rôle was played while the Southwest was still Spanish or French. As the tribe was already uprooted when early investigators began their studies of Indian culture and history—other, less disturbed groups gave greater opportunity for study of original traits—comparatively little work has been done on the Caddos until recent times. Swanton, dean and master of North American historical anthropology, thus fills a regrettable gap with this excellent source material. He follows the history of white contact with Caddos from De Soto, La Salle, St. Denis, La Harpe, and the 17th and 18th century Spanish missionaries, to the U. S. Agent, Sibley, and the removal of these successful agrarian tribes first into Texas, then to the Red River, to the all too well-known Indian state of extinction in reservations. Swanton rightly uses the early Spanish and French material first. His reprints of some of the most important Spanish texts (Casanas, Hidalgo, Espinosa) in the original language are most welcome. There is nevertheless some early American material (e.g. in E. James' report of Major Long's expedition) which, without adding essential facts, would have enriched his picture.

The author adds to this historical record a most interesting cross section through Caddo culture, based on the above-mentioned material, and compares these data with the basic field work of the late Elsie Clews Parsons (Notes on the Caddo, *Mem. Ann. Anthro. Assoc.*, 57, 1941). Among other items, he deals with moral standards, techniques, social usages, terms of relationship, government and warfare, trade, religious beliefs, and gives us a fascinating chapter on medicine and medicine men.

Swanton regards Caddo culture as of Southeastern type (close e.g. to Natchez and Taensa), except for the language and a rather loose matrilineal system.

SOCIAL HYGIENE YEAR BOOK, 1942. *The Program in Action in the States and Communities.*

Edited by Jean B. Pinney. Assistant Editors, Gertrude R. Luce and Reba Rayburn. American Social Hygiene Association, New York. $1.00. 9 x 6¼; 252; 1943 (paper).

Social hygiene problems, though still of the same type as in peacetime, are magnified a thousand times by war. Community social hygiene work is thus more than ever needed in wartime, and community responsibility more than ever definite. The *Social Hygiene Year Book* undertakes chiefly to present for the members and friends of the American Social Hygiene Association a summary of current events and progress on "the forty-eight fronts" and in the outlying territories of the nation. The material has been edited and prepared by various members of the staff of the Association.

Most of the material herein presented contains summaries of the social hygiene set-up in each of the forty-eight states and the territories of Alaska, Hawaii, and Puerto Rico. Under each are listed the social hygiene societies and committees and other voluntary and official agencies. A discussion is included of the work of the various state and community health departments and societies. Then follow the national voluntary agencies, classified by fields of work, and the national official agencies, including government departments whose work relates to some aspect of social hygiene. The appendix offers information relating to the American Social Hygiene Association, important letters and documents, social hygiene laws and legislation, publications and materials, and a series of charts and tables concerning prostitution and venereal diseases and their control. The book is not indexed. This up-to-date compendium—the only one of its kind available—should find a wide acceptance among all those interested in, and concerned with, social hygiene.

EGYPT AND THE SUEZ CANAL. *Smithsonian Institution War Background Studies Number Eleven. (Publication 3728.)*

By Frank H. H. Roberts, Jr. Smithsonian Institution, Washington, D. C. Free. 9¼ x 6; iv + 68 + 25 plates; 1943 (paper).

The focusing of attention on Egypt by Axis drives across northern Africa toward Alexandria, Suez, and the canal so aptly termed "the jugular vein of the British Empire," and General Montgomery's successful routing of Rommel's panzers recalls the fact that in its thousands of years of history the Land of the Pharaohs has often echoed to the tread of martial feet. One of the three oldest centers of true civilization, it has played a significant part in the schemes of many men and nations. Current writers in discussing its military and psychological importance in the present conflict stress its status as the key to the Mediterranean, as the rampart that guards the Middle East and the overland route to India, and as the vital crossroads between continents where the East meets the West. The author here tells the story of Egypt in clear, concise and highly effective form. He discusses first modern Egypt, including the country, people, games and amusements, education and social welfare, agricultural and industrial activity, and the government. The story of ancient Egypt is told next, including predynastic days, the protodynastic epoch, the dynastic period, the Persians, Alexander the Great and the Ptolemies, the Roman period, the Moslem conquest, the Mamelukes, and the

reign of Mohammed Ali. Information concerning foreign intervention and about the Suez Canal concludes the discussion. There is a selected bibliography, but no index. The generous use of carefully selected and beautifully reproduced photographic plates adds immeasurably to the enjoyment which the general reader will derive from this excellent volume.

THE NATIVE PEOPLES OF NEW GUINEA. *Smithsonian Institution War Background Studies Number Nine (Publication 3726).*

By M. W. Stirling. Smithsonian Institution, Washington. Free. 9½ x 6½; iv + 25 + 28 plates; 1943 (paper).

New Guinea is one of the largest islands of the world with a pre-war population of less than one million natives and very few other people. Interest in this country and its inhabitants has become acute due to the fact that it is and will be the theatre of modern warfare. This little book supplies authoritative information in a very condensed form on New Guinea's topography, climate, fauna, chief products, etc. The author, who is director of the Bureau of American Ethnology and had led an anthropological expedition to the Dutch part of the island, describes chiefly the native peoples of New Guinea. The latter belong to three primary stocks, namely the Negritos of the mountainous interior, the Papuans of the West coast and many lowlands, and the Melanesians of the North-East coast. Particularly in the vast interior of the island the natives have survived in an unspoiled stage of stone-age culture. Many of the tribes are war-like and hostile toward strangers, hence much remains unknown concerning their daily life and social institutions.

The booklet is richly illustrated with well reproduced photographs. The selected bibliography will be welcomed by many who find the crowded information in these few pages far too concentrated to satisfy their interest, aroused by the multitude of problems and topics that have been merely indicated.

TRAVELS IN AFGHANISTAN: 1937–1938.

By Ernest F. Fox. The Macmillan Company, New York. $4.00. 8¼ x 5½; xviii + 285; 1943.

The author, an American geologist, was commissioned to search for oil and minerals in Afghanistan, the little-known buffer state between India and Russia. Based upon a detailed diary, this well-written account represents an accurate description of the mostly mountainous country, of the difficulties of travel in a land without railroads and, indeed, very few roads of any sort, and of the people and their modes of life in villages or as nomads. The book also contains much information concerning the climate, resources, transport facilities, and administration of this remote section of Asia. The anthropologist will welcome the excellent front-view portraits of different types of Afghans, but the biologist will look in vain for any notes on the native fauna or flora. The volume is chiefly of geographical interest, but it is also an entertaining, sympathetic, and well-illustrated story of the hardships of travel in an uncivilized and rough country of strange grandeur and among rough and mostly suspicious men.

WISCONSIN'S CHANGING POPULATION. *Science Inquiry, Publication IX. Bulletin of the University of Wisconsin, Serial No. 2642; General Series No. 2426.*

University of Wisconsin, Madison. 8¾ x 5¾; 90 + 1 folding map; 1942 (paper).

The central theme of this bulletin, to quote President Dykstra, is "that on the quality of a nation's human resources rests its ability to survive and to push civilization forward." *Science Inquiry* is not a formal division of the University of Wisconsin but it is a voluntary cooperative effort on the part of staff members. In the present bulletin, twenty-four specialists have taken part in discussing the settlement and population growth of the State of Wisconsin, quantitative trends and qualitative aspects, factors influencing the quality of future generations, state agencies serving human needs, economic considerations, and the rôle of education. The last chapter gives a summary of findings and presents recommendations towards a better conservation of Wisconsin's human resources. A map is given showing the distribution of the people of Wisconsin according to ethnic stocks in 1940. Tables and graphs accompany the textual material and there is a bibliography of 23 titles.

ZOÖLOGY

INSECT INVADERS.

By Anthony Standen. Houghton, Mifflin Company, Boston. $3.50. 9 x 6; xv + 228; 1943.

Insect Invaders is designed to entertain and instruct those who do not demand a highly technical knowledge of the insect world, but who nevertheless wish to know something about insects in their relation to man.

This book is clearly and humorously written. The reader is given a general description of the anatomy, physiology, and classification of insects and their relatives. Greatest emphasis, however, is placed on the rôle which insects play in human affairs, since they are our chief competitors for food, clothing, and shelter on this planet.

Both harmful and beneficial insects are described, and estimates are given as to the value of the good or damage which they do. Besides menacing our mate-

rial wealth, insects are often vectors in the transmission of deadly diseases. So it is that we must continuously make war on them. The battle is one which could be lost.

Methods of combating insect hordes are described, particularly with reference to susceptible stages in the insect's life cycle. Although not always a successful measure, the use of insect predators and parasites to accomplish this makes a fascinating story.

Insect Invaders is a worthwhile book since it not only entertains, but gives the reader a wholesome appreciation of a serious problem which faces all of us. It also tells us how we can do something about it.

THE MAMMALS OF EASTERN UNITED STATES. *An Account of Recent Land Mammals Occurring East of the Mississippi.*

By William J. Hamilton. Comstock Publishing Company, Ithaca. $4.00. 9¼ x 6½; 432; 1943.

There are left today, in the eastern area of the United States, 253 species and sub-species of indigenous land mammals. This volume deals systematically with all of these, giving for each the essential facts regarding appearance, habits, and range. The author has rendered a great service to mammalogists as well as to laymen in collecting and selecting the vast and previously scattered information on our native mammals and by presenting his work in a comprehensive, accurate, and readable form.

The scarcity or abundance of species within the various major groups of our mammals is indicated by the numbers of pages assigned to these groups, namely: Edentates, 4; marsupials, 5; hoofed animals (all of the deer family), 10; rabbits (Duplicidentata), 24; insectivores, 46; bats, 50; carnivores, 84; and rodents (Simplicidentata), 177. The first two groups contain only one species each, whereas the last-named group contains 51 different species and many additional subspecies.

In the introduction it is pointed out that a great deal remains to be learned concerning our eastern mammals. Thus, "the young of only 45 have been described; the gestation period of but 25 is certainly known; detailed data on the food habits of less than 20 per cent have been recorded. The home life, seasonal differences in food habits, activity cycle, and behavior are known in any detail for less than a dozen."

This scholarly work is illustrated by over 150 good illustrations and by many useful maps, outlining the distribution of species and subspecies. Nearly 200 of the most important publications on these mammals are listed in an appendix and there is a detailed and convenient index. The volume is Number 11, in *Handbooks of American Natural History*, edited by A. H. Wright.

THE ANOPHELINE MOSQUITOES OF THE CARIBBEAN REGION. *National Institute of Health Bulletin No. 179. By W. H. W. Komp. U. S. Public Health Service, Washington, D. C.* 35 cents. 9⅛ x 5¾; ix + 195; 1942 (paper).

During the past forty years, mosquitoes have been subjected to intensive study in all parts of the world. Principally because of their economic importance as vectors of malaria, the species of the genus *Anopheles* have received the greater share of this attention, and the structure, early stages, and habits of the various species are probably better known than those of any other group of insects. According to the latest catalogue, that of Edwards, and with the addition of several species described since 1930, about 200 anopheline species are known for the entire world; of these, 63 occur in the New World. In the Neotropical region (South and Central America, the West Indies, and Southern Mexico) 61 species were known in 1940, and additions are being made constantly as new regions are explored.

This survey is an attempt to set forth our present knowledge of the anopheline mosquitoes of the Caribbean region, both from the literature and from the personal observations of the author. It deals with their known geographic distribution, their status as vectors of malaria, but more particularly with their classification and identification. It is written primarily from the point of view of the systematic entomologist, but the needs of the field man engaged in malaria control have been kept in mind. For this reason there have been incorporated numerous excellent illustrations —both drawings and photographs—and keys, the latter in both Spanish and English, together with a list of entomological terms in English, Spanish, and Portuguese, for the convenience of Latin-American workers. A bibliography and index conclude this well-written, attractively-printed and timely manual which should prove extremely valuable to the taxonomist, entomologist, parasitologist and public health worker.

CHIMPANZEES. *A Laboratory Colony.*

By Robert M. Yerkes. Yale University Press, New Haven. $5.00. 9¼ x 6; xv + 321; 1943.

More light has been thrown upon the origins and development of human behavior through study of the chimpanzee than through study of any other animal. And in this study of the chimpanzee, Yerkes long has been the leader and the chief guiding influence. It was through his efforts that the Primate Laboratory of the Yale Institute of Psychology was opened in 1925, and the more ambitious research station near Orange Park, Florida, in 1930. These ventures have yielded the major portion of our considerable existing knowledge of the living chimpanzee—not only of its psychology but also of its growth, development, and reproduction.

The present volume is a comprehensive account of living chimpanzees in captivity, based largely upon the studies of Yerkes and his staff of co-workers. In one sense, it is a sort of "swan song", for direction of the Florida research station recently has been given over to other hands. The book comprises three main parts: a general description of the living animal, a discussion of its mentality, and a section devoted to the problems of its care and handling. There are some sixty superb illustrations. The author makes no attempt to dramatize his subject, which, in fact, needs no dramatization. It is a fascinating subject, about which Yerkes has written in a highly interesting manner. He has produced a book that will be read with great interest and profit by workers in many different fields.

POISONOUS REPTILES OF THE WORLD: A WARTIME HANDBOOK. *Smithsonian Institution War Background Studies Number Ten.* (*Publication 3727.*)

By Doris M. Cochran. Smithsonian Institution, Washington, D. C. Free. 9⅛ x 6; 37 + 17 plates; 1943 (paper).

Of the close to 2,400 different kinds of snakes, less than 200 are dangerous to man, and of the nearly 3,000 known lizards, only two kinds are poisonous. The popular horror of reptiles and the wide-spread fear of snakes in jungles on the part of our soldiers are quite unwarranted, since the chances of being bitten by poisonous reptiles are exceedingly small.

This booklet describes the main characteristics of all poisonous snakes and lizards of the world in an authoritative, condensed, and clear manner. The subject is discussed according to the general distribution of these reptiles and, within each major geographical region, by the main taxonomic groups of the animals. In size, adult snakes vary from barely two feet to more than eighteen feet in length; in their habits, they can also differ very widely. There are terrestrial, arboreal, and marine forms, spitting and jumping types, aggressive and sluggish ones, etc.

Thirty-one photographs, excellently reproduced, add greatly to the value of this "handbook." There is a useful appendix on first aid treatment and one on antivenin and its preparation. In a final appendix the author gives brief directions for collecting and preserving reptiles in the fully justifiable hope that the National Museum may receive some scientific specimens from our expeditionary forces.

MEETING THE MAMMALS.

By Victor H. Cahalane. With drawings by Walter A. Weber. The Macmillan Company, New York. $1.75. 9¼ x 6½; ix + 133; 1943.

This book was prepared under the auspices of the National Park Service and is addressed chiefly to the general public visiting our numerous national parks west of the Mississippi. The last pages give convenient, systematic lists of the mammals one may encounter in each of the parks, the best localities for observation of the widely varying animal life, and page references to the description of the species in the text. The sixty-six mammals discussed range from the largest and most spectacular forms, such as grizzly bear, bison and moose, to the inconspicuous mice and chipmunks. The life history, the chief habitat and some descriptive details are given for each mammal in a vivid fashion, intended to hold the layman's interest. Of the wapiti, for instance, it is stated: "The elk is a lusty, powerful animal. He has to be. Any creature who can keep a harem of from 20 to 60 wives in order has no sinecure . . . Even if he survives the season without casualty, exhaustion and winter snows make him forget his ambitions."

This attractively printed volume is a most recommendable, popular introduction to our western mammals. Its greatest value consists in the 52 superb pen-and-ink drawings by Walter A. Weber, illustrating the animals in characteristic poses and natural settings.

OUTLINES OF ENTOMOLOGY.

By A. D. Imms. E. P. Dutton and Company, New York. $3.75. 8½ x 5½; vii + 184; 1942.

This text, by one of the world's outstanding authorities in the field of entomology, has been prepared especially for beginning students, and hence, presents the fundamentals of the subject rather than an exhaustive survey of the entire field.

The discussions are presented under such broad headings as Anatomy and physiology; Embryology, growth and metamorphosis; Nomenclature and classification; and Relationships of insects. The fundamental principles relating to the anatomy, physiology, embryology, growth, and metamorphosis of insects are derived from the study of type organisms. The section on classification includes discussions of the pertinent distinguishing characteristics; (1) presence or absence of wings, (2) type of mouth parts, (3) type of metamorphosis, and (4) features of the antennae and tarsi; the number of species; the distribution and general activities of 24 orders of insects. The final section on the relationships of insects presents discussions on the arthropods in general, with special reference to the insects; the ancestry and evolution of insects; and the affinities and mutual relationships among the insects as well as those between the insects and the other arthropods.

The volume is carefully illustrated and indexed, and carries an appendix on literature.

MONOGRAPH OF THE WEST INDIAN BEETLES OF THE FAMILY STAPHYLINIDAE. *Smithsonian Institution, United States National Museum Bulletin 182.*

By Richard E. Blackwelder. Government Printing Office, Washington, D. C. $1.00. 9⅜ x 6; vii + 658; 1943 (paper).

The Smithsonian Institution, through the Walter Rathbone Bacon Scholarship, has conducted several investigations of the fauna of the West Indies, but none, until the present study, has been concerned with the insects. The writer spent 21 months in the islands, collecting beetles of this family, and a month in London studying types. The number of specimens collected was between 45,000 and 50,000. As a result of the extensive material collected and studied, the writer has prepared this large monographic report. There are keys to the genera and species, each genus and each species being carefully and completely described. Records of the type locality, disposition and location of types, distribution, number of specimens examined, and various nomenclatural remarks are included for each species. Many of the genera are redescribed and genotypes designated, and many new species are reported for the first time. For the subfamily Aleocharinae, only a list of records is provided. The author feels that this group is hopelessly confused at the present, and until a thorough revision is made no advantage is to be gained by recording material that can not be properly identified. The volume is a landmark for West Indian entomology.

THE BIOLOGICAL CONTROL OF INSECTS.

By Hugh Nicol. Penguin Books, Ltd., Harmondsworth and New York. 25 cents. 7⅛ x 4⅜; 174; 1943 (paper).

The materials for this popular treatise have, for the most part, been gleaned from publications, museums, and authorities on the subject of insect control; hence the work represents the researches and viewpoints of numerous investigators, and incorporates no original contribution of the author except the little chapter-opening fanfares from *Through the Looking Glass, As You Like It, Alice in Wonderland, Hamlet,* etc.

An attempt has been made to bring to the attention of the lay reader, in a non-technical manner, the complexities and profundities of the control of insect pests. Discussions are included on control by parasitism with other insects as well as other animals, and by the manipulation of food supply of either the insect pest, or the parasite used to control the pest. Lists of references for (1) each chapter and (2) further reading, and an index are provided.

BIRDS FROM THE GULF LOWLANDS OF SOUTHERN MEXICO. *Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 55.*

By Pierce Brodkorb. University of Michigan Press, Ann Arbor. 75 cents. 10 x 7; 88 + 1 folding map; 1943 (paper).

The lowland area comprising the state of Tabasco, southwest corner of Campeche, and extreme northern Chiapas has a uniform climate and physiography and a homogeneous avifauna. For these reasons the term Tabascan faunal district (a minor zoogeographical area based on animal distribution) is proposed. The present list includes 300 species and subspecies of birds, of which 62 are only migrants or winter visitants, from this area. This list has been made up from published material on this region, but more specifically it is based on the collections made by Eizi Matuda in 1939. As a result of this expedition, 49 residents, 21 migrants, and 2 undescribed birds were added to the bird life of this area, as well as several forms not previously recorded from Mexico.

STUDIES OF NORTH AMERICAN PLECOPTERA *with Special Reference to the Fauna of Illinois. Bulletin of the Illinois Natural History Survey, Volume 22, Article 2.*

By T. H. Frison. Department of Registration and Education, State of Illinois, Urbana. $1.00. 10 x 6¾; 236–355; 1942 (paper).

The nomenclature and taxonomy of the stone-flies is critically reviewed in this bulletin. Merely a cursory glance of the context reveals that much confusion has existed in the proper allocation of names for these insects. To straighten out the synonymy and misidentifications, Frison has carefully examined the type material of most forms and he has thereby been able to make correct determinations. While this revision emphasizes Illinois material, the stone-fly fauna of the major portions of North America is also included. There is a key to the families, for both adults and nymphs, and to the genera. Good illustrations showing diagnostic morphological characters enhance the value of this report as an important entomological contribution.

MARINE PLANKTON DIATOMS OF THE WEST COAST OF NORTH AMERICA. *Bulletin of the Scripps Institution of Oceanography of the University of California, La Jolla, California, Volume 5, No. 1.*

By Easter E. Cupp. University of California Press, Berkeley. $2.50. 10⅜ x 6¾; 238 + 5 plates; 1943.

A much needed taxonomic report on the marine diatoms of our West Coast forms the main context of this bulletin. An effort has been made to clear up the taxonomic

problems that exist in the group, and many of the species are illustrated to facilitate future identification by other workers. Not the least interesting part is the general discussion which characterizes the diatoms from other classes of algae, and also shows their relationships. The morphology of diatoms is described as well as their biology and physiology. A section on their collection and preparation just about makes this report a complete handbook on diatoms for that region.

DISTRIBUTION AND VARIATION OF THE HAWAIIAN TREE SNAIL ACHATINELLA APEXFULVA DIXON IN THE KOOLAU RANGE, OAHU. *Smithsonian Miscellaneous Collections, Volume 103, No. 1. Publication No. 3684.*

By d'Alté A. Welch. Smithsonian Institution, Washington, D. C. $1.00. 9¼ x 6⅝; 236 + 12 plates; 1942 (paper).

This work is essentially similar to the author's earlier investigation of *Achatinella mustelina*, but the results are strangely different. An increase in moisture with lower temperature tends to increase the size of the shell of *A. apexfulva* while diminishing that of *A. mustelina*.

Further, the shell of *A. apexfulva* may be either sinistral or dextral, but the two forms tend to be geographically isolated. In any one locality one form greatly outnumbers the other.

Thirty-three new subspecies are described, and many other varieties are described without name. There is an ample taxonomic index, and a geographic index as well.

BIRDS COLLECTED DURING THE WHITNEY SOUTH SEA EXPEDITION XXVI–L. *Articles from the American Museum Novitates 1933–1942.*

American Museum of Natural History, New York City. Only unbound copies are available for sale; $3.75. 9¼ x 6; 1942 (paper).

This is a collection of papers, mostly by Mayr, which appeared between 1933 and 1942 in the *American Museum Novitates*. The papers are primarily descriptions of material collected during the Whitney expedition, with, in many cases, taxonomic reworkings of particular groups. Various other matters that are of interest not only to ornithologists but to biologists in general are also discussed, often quite briefly. Among these are variations in plumage, migration, and especially evolutionary problems. Much of the material in this group of papers has been utilized by Mayr in his recent book *Systematics and the Origin of Species*.

INTRODUCING INSECTS. *A Book for Beginners.*

By James Needham, with illustrations by Ellen Edmonson. The Jaques Cattell Press, Lancaster. $1.75. 7⅞ x 5¼; v + 129; 1943.

In answering the question "Why study insects?" the author explains that "since they affect our welfare in so many ways, we ought to know something about them." Accordingly, special attention is paid to insects useful or harmful to man, and they are considered from this practical standpoint rather than as objects of general interest.

Four chapters of the book form a useful guide for collecting, rearing and studying insects. These sections, as well as the descriptions of the insects themselves, are well illustrated.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXVIII, Part 1, Numbers 1–8.*

New York Zoological Society. Zoological Park, New York. 10½ x 7; 51 + 5 plates; 1943 (paper).

This number contains the following papers:

Biometry of Puffers and Their Parasites, by Ross F. Nigrelli and James W. Atz; The Genetics of Melanoma in Fishes. VI. Mendelian Segregation of Melanophore Reaction Types in Embryos of a Melanomatous Mother, by Myron Gordon and Fred Flathman (3 text figures); Pattern and Color in the Cichlid Fish, *Aequidens tetramerus*, by William Beebe (1 plate); A Revision of the Genera and Species of the Family Pycnonotidae (Bulbuls), by Jean Delacour (2 plates, 13 text figures); Two New Subspecies of *Pycnonotus cafer*, by Jean Delacour (1 text figure); Eastern Pacific Expeditions of the New York Zoological Society. XXXI. *Uca schmitti*, a New Species of Brachyuran Crab from the West Coast of Central America, by Jocelyn Crane (1 plate, 1 text figure); Crabs of the Genus *Uca* from Venezuela, by Jocelyn Crane (1 plate, 1 text figure). Observations on the Electric Discharge of *Narcine brasiliensis* (Ölfers), by R. T. Cox and C. M. Breder, Jr. (4 text figures).

DESCRIPTIONS AND FIGURES OF NEW FISHES OBTAINED IN PHILIPPINE SEAS AND ADJACENT WATERS BY THE UNITED STATES BUREAU OF FISHERIES STEAMER "ALBATROSS." *Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. United States National Museum, Bulletin 100, Volume 14, Part 2.*

By Henry W. Fowler. Smithsonian Institution, Washington, D. C. 10 cents. 9⅞ x 6; 53–91; 1943 (paper).

PROCEEDINGS OF THE CALIFORNIA ACADEMY OF SCIENCES: *Fourth Series. Volume XXIII. No. 35, Mammals of the Clearwater Mountains, Idaho*, by Robert T. Orr. *No. 36, Mollusks of the Clearwater Mountains, Idaho*, by Allyn G. Smith.

California Academy of Sciences, San Francisco. 10 x 7¼; No. 35:511–536 + 3 plates; No. 36:537–554 + 1 plate; 1943 (paper).

SOME AMERICAN GEOMETRID MOTHS OF THE SUBFAMILY ENNOMINAE HERETOFORE ASSOCIATED WITH OR CLOSELY RELATED TO ELLOPIA TREITSCHKE. *Proceedings of the United States National Museum, Volume 93, No. 3159.*

By Hahn W. Capps. Smithsonian Institution, Washington, D. C. 9⅜ x 6½; 151 + 10 plates; 1943 (paper).

CONTRIBUTIONS TOWARD A KNOWLEDGE OF THE INSECT FAUNA OF LOWER CALIFORNIA. *No. 7. Coleoptera: Tenebrionidae. Proceedings of the California Academy of Sciences, Fourth Series. Volume XXIV, No. 7.*

By Frank E. Blaisdell, Sr. California Academy of Sciences, San Francisco. $1.50. 10 x 6¾; 171–286 + 2 plates; 1943.

REVISION OF THE GENUS PHLOEOSINUS CHAPUIS IN NORTH AMERICA (COLEOPTERA, SCLYTIDAE). *Proceedings of the United States National Museum, Volume 92, No. 3154.*

By M. W. Blackman. Smithsonian Institution, Washington, D. C. 9⅜ x 6¼; 397–474 + 4 plates; 1942 (paper).

THE TYPE SPECIES OF THE GENERA AND SUBGENERA OF BEES. *Proceedings of the United States National Museum, Volume 92. Number 3156.*

By Grace A. Sandhouse. Smithsonian Institution, Washington, D. C. 9½ x 6; 519–619; 1943 (paper).

THE NEARCTIC SPECIES OF PARASITIC FLIES BELONGING TO ZENILLIA AND ALLIED GENERA. *Proceedings of the United States National Museum, Volume 93. Publication No. 3157.*

By Wendell F. Sellers. Smithsonian Institution, Washington, D. C. 9¼ x 6; 108; 1943 (paper).

BOTANY

RIO MAYO PLANTS: *A Study of the Flora and Vegetation of the Valley of the Rio Mayo, Sonora. Carnegie Institution of Washington Publication 527.*

By Howard Scott Gentry. Carnegie Institution of Washington, Washington, D. C. $2.25 (paper); $2.75 (cloth); 10 x 6¾; vii + 328 + 29 plates; 1942.

This publication presents a study of the vegetation of the Rio Mayo, one of the principal rivers of the State of Sonora, Mexico, draining an area of approximately 6814 square miles and constituting a rather definite geographic area in the junction of desert and thorn forest regions, with a gradient from the arid lowlands up to the mesic forests of the Sierra. It is the result of the author's field work in the region from 1933 through 1939, a total of almost two and one-half years' intensive study and collection where but scanty work had been done previously. The collections comprised 3200 numbers, representing 1276 species and varieties which were determined by Standley, Pennell, Blake, and other specialists. A considerable number of endemic and subtropical species are represented in the collections, of which about 90 species have been found to be new to science, over 50 of these having been established by Standley, around 20 by other specialists, while in this list Gentry himself establishes 8 new species (notably 5 interesting species of Agave), with one new variety of Ipomoea and 7 new combinations.

The introduction by Forrest Shreve of the Desert Laboratory, where this report was in part prepared, pays tribute to the author for accomplishing the most comprehensive botanical study of any area in the Pacific drainage of Mexico, a valuable contribution to the little-known plant geography of that region, greatly extending the ranges of many plants, and adding much to the scanty existing knowledge of the interpenetration of subtropical and desert life of the two great vegetational regions which join at the Rio Mayo.

Part I begins with the geography of the region, a chapter of considerable general interest since it also presents valuable information on the routes, by roads and trails, with first-hand information on the inhabitants, industries, agriculture, location, terrain, and other characteristic features of the settlements, ranchos, and other localities referred to as sources of the collections. Then follows a general discussion (25 pages) of the vegetation of the four major divisions: the thorn forests, short tree forests, oak forests, and pine forests, characterizing the subdivisions of these based on local topographic, soil, and climatic conditions and listing in habitat tables the characteristic plants of the typical habitats from the peaches of the thorn forest along the coast up through the mesas, arroyos, and trailways to the hilltops and ridges, and describing briefly some of the more interesting local plant associations isolated in the midst of different vegetation. A plant census with careful population counts in March and April gives the characteristics of 7 representative typical plots, two in the thorn forest, two in the short tree forest, two in the oak forest, and one for comparison in the transition from the thorn forest to the short tree forest in the Rio Fuerte water shed, with interesting analyses of succession in certain areas disturbed by man, such as recently or long abandoned milpas.

Part II, the annotated list of plants, comprising over half of the book (205 pages), lists the plants according to the classificational scheme of Dalla Torre and Harms giving, in addition to their distribution and habitat, field notes on their habit, seasonal development, abundance, and local uses, with in many cases the Mexican and also the Maya and Warihio Indian vernacular names. The illustrations in 29 plates effectively supplement the descriptions.

The final index of 10 pages effectively covers references by scientific and vernacular names to the plants mentioned, both in the descriptive part of the text and

in the annotated list. The brief bibliography of 25 titles covers the pertinent literature, while a list of specimens by families in 33 pages serves as a useful check list and gives the several herbaria in which specimens from the collections are located.

The publication is of greater human interest than are most technical treatises in this field. Practical information gained through the author's own extensive journeys through the region has been made available to other travelers. His first hand knowledge of the local uses of the vegetation is of considerable practical value. The writer is revealed as one who traveled not only as a scientist intent on his own work, but also as a sympathetic and understanding associate of the people whose existence is closely bound up with the vegetation of the region. Here and there vivid and colorful descriptions effectively and charmingly written reveal an observer sensitive and sympathetic. Phraseology such as, "He who walks this land in the month of May walks with a parched throat," is refreshingly vivid and picturesque in itself, and shows an unconscious absorption of the Spanish idiom resulting from long familiarity with the language as spoken by those close to the soil.

AN INTRODUCTION TO HISTORICAL PLANT GEOGRAPHY. *By E. V. Wulff. Translated by Elizabeth Brissenden. Foreword by Elmer D. Merrill. Chronica Botanica Company, Waltham; G. E. Stechert and Company, New York.* $4.75. $10\frac{5}{8}$ x $7\frac{1}{8}$; xv + 223; 1943 (paper).

As Dr. Merrill states in his foreword, "In this single volume students and investigators will find assembled in one place a great amount of well coordinated data that should greatly lighten their burdens and act as a stimulant to further investigations." Published in Russian in 1932 and revised in 1933, this constitutes the first part, covering general and theoretical problems, of a projected three volume work on historical plant geography.

It begins with two introductory chapters, the first outlining the scope of the subject, its relation to other branches of botany, and the methods employed in the historico-geographical study of floras, the second covering the historical background of the field.

In the next three chapters the author considers at some length areas, their centers and boundaries, their origin, and their types; while in the three following he authoritatively discusses various aspects of geographical distribution such as parallelisms in the distribution of plants and animals with the correlations between the distribution of parasites and of their plant hosts, and the artificial and natural factors in the geographical distribution of plants. Chapter 9 discusses the nature and causes of the migrations of species and floras; Chapter 10, the historical causes for the present structure of areas and the composition of floras; while the final chapter covers the concept of floral elements, geographical, ecological, and historical.

The illustrations in 35 figures supplement the text with helpful maps showing areas of distribution, while there are two indices, one of plants and animals, the other of authors.

The author, Curator of the Herbarium in the Department of Geography of Cultivated Plants of the Institute of Plant Industry in Leningrad, is widely known for his work on the taxonomy of the Scrophulariaceae and on the flora of the Crimea, as well as in historical plant geography, and the publication of this faithful translation by Miss Brissenden now makes more generally available his authoritative and stimulating discussion of these general problems in plant geography. The problems, some of which are theoretical and many of which have been subjects of intense controversy, are here treated in a dispassionately analytical manner with a judicious appraisal of the evidence on both sides. Despite the author's impersonal discussion, some of the theories and hypotheses are so controversial that undoubtedly the very clarity of the book will stimulate further extensive presentation of evidence by both sides, and it is of interest to note that even Merrill devotes part of his wholly favorable foreword to presenting evidence in opposition to Wulff's acceptance of the Wegener hypothesis of continental drift. Of necessity the author has devoted a large proportion of each chapter to clarifying the confusion that has resulted from the multiplicity of technical terms in which the field of plant geography abounds.

Although the work of Wulff himself is well known since he has published not only in Russian but in other languages more understandable to the linguistically limited reader, the publications of many of his colleagues are of necessity less familiar as they have been published in Russian alone, and one of the great values of this volume is its able presentation and appraisal of the work of such investigators as Chernova, Fursaen, Ilyinsky, Kashkarov, Komarov, Koroleva, Korovin, Kryshtofovich, Lashchevskaya, Litvinoff, Malayev, Maltsev, Maximovicz, Minayev, Mordvilko, Pachosky, Shaparenko, Sokolovskaya, Sosnovsky, Stankov, Transhel, Zinger, and others. Still further extending the scope and coverage of the book according to Wulff's own request, there is included a supplement by Hugh M. Raup noting various significant papers, chiefly in English, most of which have appeared in the 10 years between the original Russian edition and this English translation. Arranged according to chapters, these ably supplement Wulff's extensive reference lists which terminate each chapter's discussion.

The publication of this volume at the present time, despite the barriers of language difference, the hindrance of separation by half the world, and the obstacles of war conditions, is a notable achievement in cooperation between scientists of two countries allied in the war effort.

METHODS FOR DIAGNOSTIC BACTERIOLOGY. *A Complete Guide for the Isolation and Identification of Pathogenic Bacteria for Medical Bacteriology Laboratories. Second Edition.*

By Isabelle G. Schaub and M. Kathleen Foley. C. V. Mosby Company, St. Louis. $3.50. 8½ x 5½; 430; 1943.

This is the second edition of a book that has already proved its worth. It does not claim to present all of the procedures available for the diagnosis of bacterial diseases; on the other hand, its real contribution is the selection of those procedures that have demonstrated their dependability through actual routine use in a clinical laboratory. Inasmuch as the bacteriological literature is filled with methods and modifications of methods for the identifying of the same organism, it is indeed helpful, particularly to the inexperienced, to have presented those that are known to be practical and reliable.

Simply stated the book consists of explicit directions for determining the identity of bacteria present in clinical and autopsy material. It is organized in a day-by-day manner starting with the first inoculations and proceeding to the final identification. In some instances the directions go beyond the demands of the average clinical laboratory, but have been included for instances where complete and definite identification is desired. Serological methods for studying bacterial organisms and patients' sera are given. Several of the later chapters are devoted to the direction for preparing the culture media, reagents, and stains that are recommended in the foregoing procedures. As far as the reviewer can determine without actually repeating the procedures, no necessary instructions have been omitted.

The new feature of the second edition is a chapter outlining the methods for the rapid identification of commonly occurring pathogenic bacteria by colony characteristics. This should constitute a definite contribution to the field of diagnostic bacteriology inasmuch as the life of the patient in many instances may depend upon the physician being informed of the pathogen within twenty-four to forty-eight hours.

The book is attractively bound and printed. The pages are tinted a light green color in order to be easier on the reader's eyes. Space is provided on the back of each page for the jotting down of notes. A well organized index concludes the book.

THE GREEN EARTH: *An Invitation to Botany.*

By Harold William Rickett. Jaques Cattell Press, Lancaster. $3.50. 9⅛ x 6¾; 353; 1943.

The author, a botanist of wide experience, has written this book to give the layman some understanding of the relationships of man to earth. The keynote is sounded in the following quotation: "All food is from plants, all plants from the earth: *omne vivum e terra*". It is pointed out that the area of land needed for the sustenance of an individual is about two and one-half acres. Methods and culture have varied this figure in the past and may be expected to do so in the future. Further advances in our knowledge of fertility, of plant diseases, of the production of more abundantly yielding varieties, etc. will undoubtedly reduce the area. But there is always a minimum beyond which man can not go. The author warns that we must not be misled by the claims of "soilless agriculture". While it is conceivable that all the food a man can eat might be produced on a few square feet in a green house lighted by electricity and kept at a suitable temperature, the fact remains that the salts, which make the fertilizing fluid, come from the soil.

Our dependence upon plants as a source of energy is discussed. "Man is unique in using energy liberated from organic material external to his body, external to all living bodies. He warms his house, he creates light to turn night into day, he transports himself and great masses of material over the earth and sea; all by burning fuel." The present time the author calls a "spend-thrift age" in which we are spending energy far more rapidly than it is being laid up for us. He does, however, console his readers by saying that with the proper application of our knowledge of plants it is possible to produce more food than needed and to obtain fuel for transportation, etc., from plants raised especially for these purposes.

The book is not a popularization of botany in the sense that it is emptied of everything complex or controversial. As a matter of fact, the content equals that of a general textbook and contains a wide variety of information. It is written in a simple, easy, fluent style with a minimum of technical terminology. Its appearance now is rather timely in view of the wide interest in gardening and plants in general.

TREES AND TEST TUBES. *The Story of Rubber.*

By Charles Morrow Wilson. Henry Holt and Company, New York. $3.50. 8¼ x 5¼; xii + 352; 1943.

Rubber is undoubtedly one of the most commonly discussed commodities of the present day. When the news came that not only was there a serious shortage, but that the chief source of the world's supply had been cut off indefinitely by Japan's conquest of Malaya and the Dutch East Indies, the American people became suddenly aware of the importance of "this unique substance which they have been abrading away at 60 mi. per hour with the greatest unconcern". Why, if Brazil is the home of the best rubber, was it not developed there instead of on the other side of the world; why cannot some other natural substance which is readily

available be substituted for it; and above all—why has there been so much bickering and squabbling about synthetic rubber?

In this most interesting and illuminating book we find the answers to many of the questions which are uppermost in our minds. The author has surveyed the rubber situation in a realistic, practical way. He sets out to acquaint his readers with the Amazon jungles and the Far Eastern islands, and with the economic, political, and physical aspects of rubber cultivation. The work of the pioneers of the modern rubber industry, especially Charles Goodyear, is described most interestingly. It is emphasized that although some of the synthetic rubbers are superior, none of them behaves exactly like natural rubber in every way. "In spite of all the hullabaloo about the wonders of synthetic rubber, the fact is that if a dependable, permanent supply of natural caude could be assured, our present crisis would be infinitely less acute."

The complete text of the Baruch Report is included in the volume and a bibliography and an index are provided.

FIELDBOOK OF NATIVE ILLINOIS SHRUBS. *Illinois Natural History Survey, Manual 3.*

By Leo R. Tehon. Natural History Survey Division, State of Illinois, Urbana. $1.25. 7⅛ x 4½; 307; 1942.

Over 200 species of shrubs and woody vines growing in Illinois either as native or naturalized introductions are described in this handy field book. Keys and well-drawn pen and ink illustrations help make identifications as easy and as correct as possible. With the description of each species there is also recorded the time of flowering and fruiting, the general appearance of both fruit and flower, and the distribution of the species, including its preferred habitat. An excellent local fieldbook.

PRACTICAL FORESTRY IN THE HUDSON HIGHLANDS. *The Black Rock Forest Bulletin No. 12.*

By Henry H. Tryon. The Black Rock Forest, Cornwall-on-the-Hudson. 50 cents. 9 x 6; 50; 1943 (paper).

MORPHOLOGY

CONTRIBUTIONS TO EMBRYOLOGY. *Volume XXX, Nos. 187 to 197. Carnegie Institution of Washington Publication 541.*

Various Authors. Carnegie Institution of Washington, Washington, D. C. $5.00 (cloth); $4.50 (paper); 11½ x 9; 245 + 53 plates; 1942.

Readers of the *Contributions to Embryology* will feel particularly gratified to find that this volume is dedicated to George Linius Streeter, distinguished Director of the Department of Embryology and successful editor of the *Contributions to Embryology* from 1917 to his retirement in 1940.

In this issue Streeter has contributed the first of a proposed series of papers on "Developmental horizons in human embryos" in which he plans to describe the structural organization of the embryo during its first seven weeks of development. A tentative subdivision of this period contemplates 25 age groups. This first issue of the series includes age groups XI, 13 to 20 somites, and XII, 21 to 29 somites. Other groups are to follow, the earliest being reserved for the last, in order to take advantage of the many important new specimens which have been added recently to the Carnegie Collection.

A presomite human embryo with chorda canal and prochordal plate is described by W. C. George. As usual with embryos picked up "impromptu surgically", as this was, the ovulation age can only be estimated by comparison with other human embryos or with monkey embryos of known ovulation age. The age is probably somewhere about 18 or 19 days.

Two other papers dealing with human material are found in this volume. One by Thomas R. Forbes on the fate of the medullary cords of the ovary and the other by Fidel Cuajunco on the development of the motor end plate. Forbes studied serial sections of ovaries of 44 fetuses of 100–424 mm. C.-R.L. and of 11 infants and children of 6 weeks to 3½ years of age. HE found that the medullary (primary sex) cords begin to regress at about 150 mm. C.-R. L., and usually disappear when the fetus reaches a C.-R.L. of 280 mm. These cords were absent from all the infants' and children's ovaries examined. Cuajunco reports the results of a histological study of the development of the motor end plate in m. biceps brachii from 25 human fetuses ranging in age from 10 to 39 weeks. He concludes from his study that the nerve fiber which innervates the extrafusal muscle fiber brings the nuclei of the sole plate along with it. That is to say, the nuclei of the motor end plate are neurilemma nuclei rather than modified nuclei of the muscle fiber.

Four papers in this volume deal with the monkey. The fate of the corpora lutea and the nature of the corpora aberrantia in the rhesus monkey are described by George W. Corner. It appears that the somewhat puzzling corpus aberraus represents an alternative mode of retrogression of the corpus luteum of the cycle. Why certain corpora lutea pass into this state of prolonged existence resembling the corpus of pregnancy rather than degenerate in the usual manner is not yet clearly understood. Sections of the ovaries described in this paper were restained for luteolipin by I. Rossman and the results incorporated in his contribution entitled "On the lipin and pigment in the corpus luteum of the rhesus monkey". Rossman reports that his estimates of the age of the various standard corpora lutea in

retrogression agree very well with the ages established by experiment. Apparently the accumulation of luteolipin makes it possible to estimate the age of the retrogressing corpus with a fair degree of accuracy.

Carl G. Hartman reports further attempts to cause ovulation in the adult rhesus monkey by means of gonadotropes. After a thorough testing of the gonadotropic activity of various potent extracts, he recommends the original method of Hisaw, Fevold and collaborators, which consists of building up the follicle slowly with potent FSH and finally precipitating the rupture of the nearly ripe follicle with FSH and LH. Hartman also states that human chorionic hormone (APL) has not proved a good ovulating "luteinizer".

The fourth and last paper dealing with the monkey is of quite different character. Here we have a very interesting account of the development and regression of reflexes, postures, and progression in the young macaque, by Marion Hines. Thirty-one animals were used; 5 were fetuses removed by Caesarean section. Particular attention was given to the mode of progression, the posture assumed in sitting and standing, the differential distribution of muscle tone at different ages, the superficial and deep reflexes, the general use of the body, such as rhythmic patterns and discrete movements made in response to tests or self-initiated, the responses to ordinary sensory stimuli, and the interreactive behavior of baby and mother. The author points out that from a neurological point of view the order of the development of the monkey infant and the human infant is strikingly similar. The numerous and excellent photographs of the baby macaques are particularly appealing.

There are two papers on the opossum: one, a histological study of the ovary by Pedro Martinez-Esteve in which it appears that the histological pattern is essentially that of mammals in general; the other by Robert K. Burns, Jr., which deals with the origin and differentiation of the epithelium of the urinogenital sinus and the modifications induced by estrogens. The injections of crystalline sex hormones bring about unusual reactivity of the sinus and its derivative structures. The stratified epithelium undergoes intense squamous hyperplasia followed by continuous development and shedding of the keratinized layers, the final appearance being identical with that of the adult mammalian vagina at estrus. The fact that in the experimental embryos, keratinization occurs first in the lower sinus and progresses gradually upward into the basal region of the bladder and the sinus horns leads the author to the conclusion that the proctodaeal region or "ectodermal cloaca" is the original source of the cornifying tissue. The use of a hormone to call forth precociously familiar visible changes which make a tissue readily identifiable at all stages is extremely interesting and certainly unique.

The embryology of *Eleutherodactylus nubicola*, an anuran which has no tadpole stage, is described by W. Gardner Lynn. In this genus, the eggs are laid on land and hatch into tiny frogs like the adult. This terrestrial development is accompanied by many important changes in the embryonic history of nearly all of the organ systems. Since so few of the anurans known to lack the usual aquatic larval stage have been investigated embryologically, the present contribution is a most welcome addition.

In conclusion it may be added that all eleven papers in this volume are abundantly and beautifully illustrated.

MAN IN STRUCTURE AND FUNCTION. *Volumes I and II. By Fritz Kahn. Translated from the German and edited by George Rosen. Alfred A. Knopf, New York.* $10.00. 9¼ x 6¾; Vol. I, xv + 341; Vol. II, xxvii + 401 + xiv; 1943.

This ambitious work was first published in 1939 in Switzerland under the quite different title *Der Mensch gesund und krank*. The present two volumes give a popular account of human anatomy and physiology, as the English title implies. There are added, however, many facts and discussions appertaining properly to medicine as well as to pathology, teratology, comparative anatomy, embryology, physical anthropology, biochemistry, psychology, and even child training. The most noteworthy feature of the publication consists in its 461 well reproduced illustrations, many of which are highly imaginative and most are instructive to a rare degree. At times, however, the desire for originality has gone to almost absurd extremes and some illustrations interpret the facts in a distorted fashion.

The ten major parts of this broad treatise start with a brief introduction "From electron to man" and then deal in turn with the skeleton, the musculature, circulation of the blood, respiration, digestion, nutrition, the nervous system, the skin and sensory organs, and "sex life." The author knows how to arouse and hold the interest of the layman by dwelling on the most sensational aspects of his subject matter, by introducing many and often novel comparisons with facts familiar to everybody, and by switching his discussions rapidly among widely varying topics. His versatility is apparent from a glance at the subject index which ranges from "Abdomen, rumbling in" *via* "Oesophagus (gullet): sword swallowing, trick involved in" to "Zola, Emile, olfactory sense of."

This comprehensive work contains a very considerable number of erroneous statements and many others which are open to grave doubts. The author, evidently, is more at home in medicine than in biology. For instance, it is claimed naively: "the circumstance that during the nine months of intra-uterine life the human embryo 'swims about' in a fluid medium appears to be both a recollection and an indication of the fact

deduced from geological and palaeontological evidence that the earliest forms of animal life were not terrestrial but aquatic."

Between the detailed and technical explanations of man's form and function is freely interspersed good advice regarding personal hygiene. Thus, the chapter on the intestines ends with the admonition: "The older person who is constipated cannot be helped by a discussion of how he should have been trained in childhood. He can do nothing except try to make up for lost time by undergoing a regular course of intestinal training. Every day as punctually as a time-table he must try patiently and with concentration to obtain a regular evacuation." Even the moral side of man's behavior enters the discussions, e.g. "Anyone who tries to corrupt or debauch another generally tries to ply the victim with alcohol, and if possible in the form of concentrated liqueurs or cognacs."

In his conclusions the author deals with the "True problems of human biology." Here he states

> Modern man does not grow old normally like an animal, in which there is a general even aging of all the organs. Man ages unevenly; individual organs become old sooner than others because they are always under a strain due to the erect position of the body and the mode of life under civilized conditions. . . . The immediate task of human biology is not to rejuvenate old people, but to see that young people can grow old normally.

Some claims in these conclusions may be doubted by expert biologists.

In spite of its many shortcomings, this work is to be recommended to laymen and even to medical students and this particularly on account of the great number of novel and stimulating illustrations.

THE HUMAN HAND.

By Charlotte Wolff with a Preface by William Stevenson. Alfred A. Knopf, New York. $3.00. 8¾ x 5⅝; xvii + 198 + 24 plates + vi; 1943.

This is an attempt to place chirology—the reading of hands—upon a respectable, scientific basis. The author aims to produce a "psychology of the hand" based upon studies of normal and abnormal individuals, and anthropoid apes and monkeys. This "psychology" attempts chiefly to "comprehend the constitution of man, the structure of personality." To this end, observations are made of the main external manual features, such as general form of the hand, form of thumb and other fingers, flexure lines, dermatoglyphics, and nails. Hands are described in terms of constitution, temperament (stated to be largely dependent upon the endocrine glands and the autonomic nervous system), mentality, and vocation. When these are brewed together, six main classes of hands emerge. The individual digits are endowed with special constitutional significance: they are regarded by the author as fundamentally related to certain internal organs and thus as indicating various pathological states. Hence the thumb is said to be related to general vitality, the index to the respiratory system, the medius probably to the abdominal viscera, and the minimus to the endocrine glands and, especially, the gonads, thus reflecting (or controlling?) the sex life. For the moment, apparently, the annularis remains a chirological orphan. Furthermore, the author finds that the two hands differ in their capacities for revelation and enlightenment. Her studies support the old chiromantical belief that the left hand shows "what we are" and the right hand "what we have become."

The book contains a number of gross factual errors and dogmatic statements that are open to question. The neurology expounded is hardly of a text-book type. No distinction is made between touch and proprioceptive sensibility; in fact, they repeatedly are regarded as one and the same modality. The prefrontal area of the cerebral cortex and area 6 are confused; so are the terms "epicritic" and "protopathic."

The musculature of the human thumb is described as "peculiar"—a misconception that is not limited to the author. Primitive man is said to have been ambidextrous, although the basis of this claim is a mystery. From her own manual studies, the author is inclined to believe that man and the anthropoid apes have evolved independently from a common New World monkey stock—a novel contribution to anthropological theory! Finally, such assertions as those to the effect that "power of consciousness is more highly developed in Europeans than in Negroes" and that left-handedness is a sign of degeneration, scarcely need comment.

That the hands may reveal much to the astute observer is not to be denied (one needs only mention that well-known monograph "Upon the Influence of a Trade upon the Form of the Hand," by Sherlock Holmes). Yet whatever Doctor Wolff's "psychology of the hand" is, as expounded in this volume, it is not a science. It is a curious mixture of fact, theory, hypothesis, and conjecture. Indeed, the author herself states that it is "an art as well as a science," and that "intuition," which is a "gift and not a thing that can be learned," thus plays a considerable rôle. One can only wish that the author had more consistently kept a distinction between intuition and scientific fact in mind.

VERTEBRATE PHOTORECEPTORS.

By Samuel R. Detwiler. The Macmillan Company, New York. $4.00. 8¾ x 5⅝; x + 184; 1943.

In the present volume the author has given us an interesting account of the structure, distribution and physiology of the visual cells (rods and cones) of the vertebrate retina. After a brief description of the bulb

as a whole, by way of introduction, a clear account of the structure of the retina and the retinal elements is presented. The author points out that the Duplicity Theory should be regarded now as fact rather than theory, in view of the indubitable support it has received from physiologists in recent years. Thus, the retina is to be regarded as a dual sense organ.

The close correlation between the structure of the retina (the presence, distribution, etc. of the rods and cones) and the mode of life of an animal (whether diurnal or nocturnal) is well demonstrated in a chapter entitled "Retinal structure and animal habits."

The various structural changes which the retina exhibits in response to illumination of the eye such as movements of the pigment in the epithelial cells, changes in the form and length of the visual cells, and changes in the form and staining reactions of the retinal nuclear layers are described, as well as the different theories held to account for the adaptive significance of these responses. It is pointed out that none of the many explanations for these photomechanical responses has really fully satisfied all of the conditions, owing mainly to the lack of uniformity of the light response throughout the vertebrate groups. The various specializations of the fundus far increased visual acuity, and the evolutionary relationships and the functional significance of the fovea are discussed in some detail.

In a chapter on retinal photopigments the properties of both rhodopsin and porphyropsin and their relations to vitamin A are discussed. Certain histological entities in the fixed retina are believed by the author to be identified with retinene—the intermediate decomposition product between vitamin A and visual purple. The final chapter is concerned with recent experimentation on the effects of dietary deficiencies on the visual cells. Recent observations show not only that vitamin A deficiencies affect the physiological thresholds of the visceral elements, but that prolonged avitaminosis A may bring about structural breakdown of the rods. Evidence is presented to show that degenerated rods in rats are able to undergo repair following prolonged feeding on an adequate diet. The theoretical possibilities of such structure changes in the human retina are considered in relation to the varying periods of time required by many persons to recover normal vision after vitamin A depletion.

As a whole the book is readable and interesting. The material is well selected and synthesized and the illustrations are good. It should prove useful to both biologists and physiologists who have a general interest in the vertebrate eye. It is not intended for specialists.

SOMATIC AND ENDOCRINE STUDIES OF PUBERAL AND ADOLESCENT BOYS. *Monographs of the Society for Research in Child Development. Volume VII, No. 3 (Serial No. 33).*

By William Walter Greulich, Ralph I. Dorfman, Hubert R. Catchpole, Charles I. Solomon, and Charles S. Culotta. Society for Research in Child Development, National Research Council, Washington, D. C. $1.50. 9 x 6; vi + 65 + 10 plates; 1942 (paper).

A report of a cooperative study of "some somatic and endocrine changes associated with puberty and adolescence in boys." The members of the Adolescence Study Unit of the School of Medicine and the Institute of Human Relations of Yale University represent the following departments of the University: Physiology, Physiological Chemistry, Pediatrics, Psychology, and Anatomy. The report is interesting from two aspects, the cooperative approach to the problem and the results obtained. The joining of forces within a University for tackling a general problem of this kind undoubtedly has many advantages, as the present report indicates.

In the somatic studies of puberal and adolescent boys the following subjects are discussed: primary and secondary sexual characters, the order of appearance of some external changes associated with sexual maturation in boys, a proposed method of classifying puberal and adolescent boys, the skeletal status and maturity groups. In the endocrine studies, the first part is concerned with the determination of estrogenic and androgenic substances in the urine of boys; the second, with the determination of pituitary gonadotropic hormone in the urine of boys. Graphs, tables, and many figures are included in the study and there is a bibliography of 77 titles. The report of the study of some behavioral aspects of adolescence is not included in the present volume.

ATLAS OF HUMAN ANATOMY *with Explanatory Text. New Edition.*

By Franz Frohse, Max Brödel, and Leon Schlossberg. Edited with Explanatory Notes by Jesse Feiring Williams. Additional Section on The Endocrine Glands; Illustrations by Leon Schlossberg and Descriptive Text by Charles F. Geschickter. Barnes and Noble, Inc., New York. $2.25 (cloth); $1.50 (paper). 8¼ x 5⅜; 86; 1942.

This pocket atlas of human anatomy is a reproduction in miniature of the well-known Frohse-Brödel series of wall charts. Its second edition includes a section on both gross and microscopic anatomy of the endocrine glands, with illustrations by Schlossberg. These new illustrations maintain the high standards set by those executed by Frohse and Brödel. The reproductions of the entire set are uniformly excellent. The text makes no attempt at erudition, but is aimed at the intelligent layman.

Although this book is not designed to replace the standard, larger anatomical atlases, it will have a wide appeal. Its very compactness and comprehensiveness,

not to speak of the truly magnificant quality of its illustrations, make it eminently suitable for a variety of uses.

THE NEUROMUSCULAR MATURATION OF THE HUMAN INFANT.

By Myrtle B. McGraw. Columbia University Press, New York. $2.00. 8½ x 5½; ix + 140; 1943.

This careful and useful study of the behavior development of the growing human infant primarily deals with sequential changes in specific functions. These are expressed in those motor activities common to infant and young child. The author endeavors to depict the rôle of the cerebral cortex in each function. An attempt is made to correlate changes in behavior with histological structure of the cortex. Such correlation, however, at the present time of necessity is quite incomplete.

The presentation would have profited by a more comparative viewpoint, especially with regard to other primates. Considerable data along these lines now are available, notably those gathered by the Yerkes group for the chimpanzee and Marion Hines' recent study of the infant rhesus monkey.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 51, No. 3. The Origin and Differentiation of the Larval Head Musculature of Truturus torosus (Rathke), by Arthur Rempel.*

University of California Press, Berkeley. 50 cents. 10¼ x 6¾; 29 + 12 plates; 1943 (paper).

PHYSIOLOGY AND PATHOLOGY

A HISTORY OF TROPICAL MEDICINE. *Based on the Fitzpatrick Lectures, Delivered Before the Royal College of Physicians of London, 1937–38. In Two Volumes. By H. Harold Scott. Williams & Wilkins Company, Baltimore.* $13.50. 9 x 5¾; Vol. I, xix + 648; Vol. II, iv + 649—1219; 1939.

Sir Harold Scott's book is based on his Fitzpatrick Lectures, delivered before the Royal College of Physicians of London, 1937–1938. A first English edition came out in 1939, but a great part of it was destroyed by bombs in September, 1940. Thus this second edition, which is the first one to be issued in the United States, was necessary. Scott is well known for his work in Jamaica and Hong Kong and as Director of the Bureau of Hygiene and Tropical Diseases.

The author first surveys, in about 100 pages, the classic hunting grounds of tropical diseases: navy, army, colonies (all British of course), dominions, and India. This is undoubtedly the weakest part of the book. The author has a tendency at times to be unsystematic, and his unscientific prejudices of race and class sometimes break through in spite of his efforts to dominate them. He passes then to the real substance of the book: large monograph-like chapters on malaria, yellow fever, trypanosomiases, leishmaniases, leprosy, plague, undulant fever, relapsing fever, meliodosis, dengue, amoebic dysentery, ankylostomiasis, avitaminoses and poisonous foods. The author gives the history and distribution of each disease and the history of our knowledge and our methods of treating these diseases.

The volume is what every medico-historical book should be, but so few actually are: it is much more than a historical book, it is a true medical book. Relying not only on a tremendous knowledge of history but on extensive practical experience the author is not so much discussing philological subtleties as the impact of historical experiences on actual problems of research, prevention, and treatment. He is very fair in reporting the accomplishments of research workers who are not his compatriots. This also is a quality we very often sadly miss with historians, medical and others. The book is very much up to date, embodying the experiences of the Abyssinian War. Recent progress of tropical medicine since 1939 is reported in an appendix of 50 pages.

The author closes with chapters on the building of the Suez and Panama Canals, the Slave Trade and 15 very short biographies of leading men in tropical medicine, from Bontius to Ross. These biograpical sketches help Scott to correct some omissions (e.g. concerning the rôle of James Lind who in the first volume is badly neglected in favor of Gilbert Blane), and they remind us of the enormous (and in its effect, criminal) resistance of administrative bodies against which men like Gorgas had to fight, e.g. in Panama. It is true that Gorgas is, and will be, remembered while Admiral Walker and Colonel Goethals are forgotten; but that cannot bring back to life those who died in Panama who could have been saved. One hopes that our Gorgases today have more sensible superiors.

It is hard to find adequate terms of praise for this extraordinary book. It is the kind of work we have been waiting for since Hirsch's *Handbook of Geographical and Historical Pathology* became obsolete. It is difficult to imagine a scientist, nay, an educated person, who would not be interested in this book for one reason or another.

CYTOLOGY AND CELL PHYSIOLOGY.

Edited by Geoffrey Bourne. Clarenden Press, Oxford; Oxford University Press, New York. $6.00. 9½ x 6; xi + 296; 1942.

In this volume nine specialists discuss cytology and

cell physiology under the following headings: (1) Some aspects of cytological technique, J. R. Baker; (2) Physical and physicochemical studies of cells, Part I. General, J. F. Danielli; Part II. Monolayer technique, J. H. Schulman; (3) The cell surface and cell physiology, J. F. Danielli; (4) Mitochondria and Golgi apparatus, G. Bourne; (5) Nucleus, chromosomes and genes, M. J. D. White; (6) Microincineration and the inorganic constituents of cells, E. S. Horning; (7) Enzyme systems of cells, H. Blaschko and W. Jacobson; (8) Pathological aspects of cytology, R. J. Ludford.

Since Wilson's synthesis of cytological knowledge there has been a tremendous increase in means of approach to the subject and in established facts, but above all, in facts concerning cell physiology. More and more a new synthesis of the innumerable and diversified data on cell structures and their functions, won in many different fields of study, has become imperative. Is such a synthesis possible today? The present volume seems to indicate that there are still too many gaps. It is thus not a synthesis but a mosaic of more or less connected reviews of the various fields contributing to cytology today. Their study makes it obvious, however, that the common ground upon which to build the new theory of the cell lies in the study of molecular structure and molecular forces.

The separate reviews are not complete discussions of the various fields, but emphasis has been laid on some recent techniques and discoveries which are important for the cytologist. The selection is on the whole very good. It is clear from the nature of the book that it is not, and was not intended to be, a text book. It is a reference book for the research worker and the advanced student. But its value does not lie solely in the amount of material, which is presented in a clear and understandable fashion, but also in the spirit of cooperation and correlation between various fields, from morphological cytology, genetics, physical chemistry, protein chemistry, enzyme chemistry, X-ray physics to bacteriology and pathology. It therefore belongs on the desk of every cytologist. If it can impress on the working cytologists the close relationship of all these sciences to his particular work and the fruitfulness of a synthetic, yet not dilettante, working habit, it will have done much for the advance of cytology.

Considering the conditions under which the book was written, during the air blitz on Britain, we cannot but congratulate the authors on their symposium and agree with the foreword of R. A. Peters: "The spirit is indeed hard to crush."

MIRACLES OF MILITARY MEDICINE.

By Albert Q. Maisel. Duell, Sloan and Pearce, New York. $2.75. 8⅜ x 5½; xiv + 373; 1943.

The very title *Miracles of Military Medicine* foretells the fascinating subject of the book. With so many of our men fighting the world over, it is comforting to read about the care that modern medicine is capable of giving—in many instances, it actually would seem to border on the supernatural.

The miracles that are discussed in this book include the treatment of shock, burns, and compound fractures; the discovery and use of new drugs and anaesthesia; the development of improved surgery; the invention of mechanical and electrical aids to medicine; the advances of plastic surgery; and the activities of the flight surgeons in selecting and protecting our aviators. The pages are filled with facts and a certain amount of fiction that together make the book entertaining as well as instructive. However, it must be said, that on a few occasions the author's enthusiasm to emphasize the nature of a miraculous advance makes it difficult for the reader to clearly distinguish between fact and fiction.

Inasmuch as the laity acquires most of its facts on scientific subjects from popular books of this kind, it is important that the authors be accurate in their statements of the facts that are presented. One feels certain while reading this book, that Maisel felt this responsibility and made every effort to meet it. However, a few minor mistakes have made their appearance. For example, he states that Penicillin is "brewed by bacteria that live in the soil" when in truth it is produced by a mold that was isolated from the air. Such errors are minor, almost purely academic, and do not seriously subtract from the worthiness of the book.

PHYSIOLOGICAL REGULATIONS.

By Edward F. Adolph. Jaques Cattell Press, Lancaster. $7.50. 9¾ x 6¾; xv + 502; 1943.

This work is neither a textbook nor simply a review of the literature on physiological regulation, but is rather a report on a series of original investigations that became too extensive for presentation in a journal. The investigations started with the question: "What do animals do to maintain their physiological constitutions and activities?" The answer to this question takes the form of the present 500-page volume, which may be regarded as a significant contribution to the field of physiometry.

According to the author, the term "regulation" has appeared in physiological writings since about 1870, and is used currently to denote the balances, variabilities, recoveries, and behaviors which are related to the vital attributes and properties common to living organisms.

Part A deals with the regulation of body water in a number of organisms subjected to various experimental conditions. The observations are measured quantitatively and treated statistically, then discussed in the

light of such analysis. With respect to the content of water in the body of the dog, the following rather obvious conclusions are drawn: (1) gain and loss of water are equal at only one content (balance); (2) in all excesses, losses are faster than gains; and (3) in all deficits, gains are faster than losses.

Part B deals with the physiological regulation of heat, oxygen, carbon dioxide, glucose, lactate, heart rate, blood pressure, regeneration of tissue, etc., in a number of organisms, as well as the uniformities and interrelationships among various components of the physiological patterns of such organisms.

The meticulous and detailed delineation or the quantitative observations of the investigations, as well as the numerous excursions into the realm of speculation, make the task of reading the book a slow and arduous one. However, the compensating factor in this respect is that the essence of each chapter is summarized for general consumption, and the experimental details may be left for those interested in the actual mechanics of the experiment.

The work is well illustrated and documented and carries a detailed index.

A Surgeon's Fight to Rebuild Men. *Autobiography. By Fred H. Albee. Foreword by Lowell Thomas. E. P. Dutton and Company, New York.* $3.50. 8⅛ x 5¼; 349; 1943.

Honors, decorations, recognition, fame have come to Dr. Albee from every quarter of the globe. He has been decorated by 16 different countries of Europe and South America. In a recent visit to Brazil, he was the guest of the Brazilian Government and dedicated an operating room named for him at the University of Brazil Hospital for Accidents. Albee sprang into international fame during the First World War because he could mend a broken leg that refused to heal, fasten together a fractured elbow, perform miracles of bone surgery. He did one half of all the bone-graft operations in the American Army at that time. After the War he became intensely interested in the problem of human rehabilitation. He feels that one of the most important problems facing our world today is the salvaging of man power in both war and peace. Thousands of young men wounded in this present war, he believes, can be reclaimed to useful citizenship. He also asserts that many of the physically unfit turned down by the Selective Service can be reclaimed and made available for the armed forces.

Albee's autobiography is the story of his early years as a pioneer of medicine and of his steady rise to the important position he occupies today as one of the great physicians of our time. He tells here of his early struggles, of the introduction of his revolutionary methods in surgery, of his travel and study in foreign countries, his positions as head of the great American health services, and of his work as a pioneer in the field of human rehabilitation. The volume is appropriately illustrated and indexed.

Biological Symposia, *Volume IX. Sex Hormones. Series edited by Jaques Cattell. Volume IX edited by F. C. Koch and Philip E. Smith. Jaques Cattell Press, Lancaster.* $2.50. 9⅜ x 6⅜; x + 146; 1942.

During the past five years, the physiology of sex has presented one of the most fertile and fascinating fields of investigation that any budding, or mature, biologist could hope to find. Some of the most pertinent of the recent developments in the field are presented in this volume in two series of four studies each.

The first series, dealing entirely with the actions and metabolism of sex hormones, includes papers by Carl R. Moore, A. T. Kenyon, Edward A. Doisy, and F. C. Koch. The first of these four authors discusses the physiological reactions of an organism to the testicular and ovarian hormones, and the relation of such reactions to the other endocrines. The second investigator presents an analysis of the metabolic influences of the sex hormones in man, together with a brief comparison of such influences with those of the adrenal sternoids. The third writer deals solely with the metabolism of the estrogens, but presents the subject from the broad viewpoint attained from experiments with rats, guinea pigs, rabbits, dogs, monkeys and man. The fourth paper covers the problem of the relation of various states of health to the metabolism and excretion of the male sex hormones in man.

The second group of four studies is concerned with the relationships between hormonal factors and the inversion of sex in the bird, the amphibia, the rat, and opossum. The general conclusion apparent in all of these studies is that for some unknown biological reason, the living organism has developed the potentiality for bi-sexual differentiation, but that it has come to rely on some influence beyond that of the germ cells *per se*, to induce the complete development of either the male or the female sex system. In all four investigations, the time element has been shown to be very important in the experimental reversal of sex.

Each paper in both series carries a bibliography, but no index to the volume is provided.

Aids to Tropical Medicine. *Fourth Edition, Revised. By J. C. Broom. Williams & Wilkins Company, Baltimore.* $1.75. 6¼ x 4; viii + 203; 1942.

This little book is the fourth edition of a publication formerly written by the late Dr. G. E. Brooke. In this revision, the original subject matter has been brought up to date, and a new section added on diseases of the typhus group. Broom has discarded the previously

alphabetical arrangement, and instead has presented the diseases grouped together according to related etiology.

The author discusses a wide variety of diseases in a concise, well organized manner. These are not entirely restricted to the tropics, but occur more commonly in such regions. The diseases considered include those caused by viruses, rickettsia, bartonella, bacteria, fungi, spirochaetes, protozoa, helminths, and vitamin deficiences. Several unclassified diseases, such as sunstroke and snake bites, are also presented. A section on entomology gives a brief account of the flies, mosquitoes, and fleas of medical importance. The identification, bionomics, and control of these insects are briefly discussed. In a final chapter on technique, the reader is instructed in the methods of examining blood films and fecal samples.

The discussion of each disease follows a strict, outline organization. The following points are discussed in the order listed: definition, synonyms, geographical distribution, etiology, vectors (if any), symptoms, diagnosis, and treatment. Naturally within the restricted scope of such a small volume, a thorough knowledge of the diseases cannot be expected to be acquired. However, the author has excellently condensed the immense amount of material on the subject of tropical medicine.

The text material is supplemented by 18 fever charts, 13 plates and figures, and 4 tables. In addition, several keys are given to aid in the identification of the insects. The book has a three-page index.

ANNUAL REVIEW OF PHYSIOLOGY. *Volume V. Edited by James Murray Luck and Victor E. Hall. American Physiological Society and Annual Reviews, Inc., Stanford University, California.* $5.00. 8¾ x 6; viii + 613; 1943.

The past four editions of the *Annual Review* have brought it such general recognition by workers in all fields of biology that a detailed review is hardly necessary. The articles are of the same general type as in previous volumes, each being a very compact, thorough, and up-to-date summary of recent investigations in a particular field. Each chapter has been prepared by one or more investigators, who rank high in the field which they are discussing, and covers fully the research work in that field the past few years. In the case of topics not recently reviewed, older work is also included. Needless to say, war-time conditions have added greatly to the difficulties of preparing such a volume. Perhaps the most serious and ever-present obstacles are the difficulty of obtaining foreign journals and the secrecy surrounding much of the current research in our own country; but lack of time on the part of authors, and transportation difficulties also combined to prevent the inclusion of several articles slated for this volume. In spite of these difficulties an excellent volume has been compiled which should follow its predecessors in becoming a standard reference work for innumerable physiologists and general biologists.

The volume includes chapters on: Physiological and pathological effects of ultraviolet radiation, Physical properties of protoplasm, Physiological aspects of genetics, Developmental physiology, Physiology of bone, Energy metabolism, The respiratory system, Muscle, The digestive system, Blood, The lymphatic system, Heart, Nerve and synaptic transmission, Visceral functions of the nervous system, Temperature regulation, Liver and bile, Sense organs, Metabolic functions of the endocrine system, Physiology of mammalian semen, Endocrinology of reproduction, Physiological psychology, and Biological assay.

Each chapter is provided with a comprehensive bibliography, and author and subject indexes covering the book as a whole complete the volume.

CLINICAL SIGNIFICANCE OF THE BLOOD IN TUBERCULOSIS. *By Gulli Lindh Muller. The Commonwealth Fund, New York.* $3.50. 9¼ x 6; xxiii + 516; 1943.

Hematology is an important tool in the management of the patient with tuberculosis. Cytological studies are sensitive indicators of active disease, while corrected sedimentation rates are reliable guides to the subsequent destruction of tissue. Such studies, therefore, are valuable as an aid in diagnosis, prognosis, in following the progression and regression of the disease and the effectiveness of various forms of therapy, and especially in evaluating the different forms of collapse therapy where physical signs and X-ray studies are obscured by the collapse. Serial blood examinations are also of importance in the selection of patients for permanent collapse by thoracoplasty.

Muller's discussion of the changes and their significance in the leucocytic formula, red cells, hemoglobin, and sedimentation rate in various stages of pulmonary tuberculosis is based upon analyses of 6819 complete hematological examinations of 1000 cases consecutively admitted to the Rutland (Massachusetts) State Sanatorium. Each examination was correlated with the objective signs and clinical symptoms found at that particular time. In addition to the presentation of her own extensive experience and findings, including a new table for the correction of the sedimentation rate, the author reviews and evaluates the extensive and heretofore uncorrelated literature bearing upon hematology in tuberculosis. The material discussed is presented in six sections: physiology of the blood-forming organs and cellular response to the tubercle bacillus, changes in the circulating blood in tuberculosis, the sedimentation rate, clinical and hematological data as measures of constitutional reaction, the effect of thera-

peutic methods, exercise, and certain complications on the hematological picture, and examination of the blood. A well-chosen series of tables and charts add materially to the effectiveness and lucidity of the author's discussion. A bibliography of over 600 items and a complete index conclude this dependable treatise on the significance of changes in the blood in the management of tuberculous patients.

LABORATORY EXPERIMENTS IN PHYSIOLOGY. *Third Edition.*

By W. D. Zoethout. C. V. Mosby Company, St. Louis. $2.25. 8½ x 5½; 256; 1943.

This is a well-prepared and comprehensive laboratory guide for a course in animal physiology. It contains 256 experiments of varying length and complexity—enough for an extensive year's course in the subject. However, the large number of experiments permits adaptation of the manual to shorter courses. The exercises are clearly written and most of them are provided with numerous thought-provoking questions.

For the performance of many experiments kymographs and stimulating apparatus are needed, but the requirement of elaborate equipment is avoided. Although a few of the exercises call for mammals and a degree of operating skill, the use of frogs and turtles, or frogs alone, will still permit the giving of an extensive laboratory course and the study of the majority of important physiological phenomena. A considerable number of experiments using the students as subjects are provided. The guide may be used in conjunction with any textbook of animal physiology since no specific references are given.

BRUCELLOSIS IN MAN AND ANIMALS. *Revised Edition. By I. Forest Huddleson. Contributing Authors: A. V. Hardy, J. E. Debono, and Ward Giltner. Commonwealth Fund, New York.* $3.50. 9 x 6; xix + 379; 1943.

This second revised edition of the 1939 issue of Huddleson's *Brucellosis in Man and Animals* will be found a valuable reference work for teachers and practitioners. It has been brought completely up to date even to giving new information not hitherto published. A detailed discussion is included of clinical manifestations and epidemiology of the disease in man.

Huddleson has broadened the scope and authority of the book by enlisting the cooperation of three investigators whose work has been outstanding in the field: Hardy, who was the first to make a complete survey of brucellosis in man in the United States; Debono, whose many years of observation of the *Brucella melitensis* type of disease in Malta have resulted in an extensive compilation of material from case histories; and Giltner, who has studied the health problems in man and animals which have evolved from the brucelloses.

Three types of *Brucella* are now recognized: *Br. melitensis*, whose chief host is the milch goat; *Br. abortus*, the cause of infectious abortion ("Bang's abortion disease") in cattle; and *Br. suis*, for which the hog appears to be the chief host. Detailed information is given on methods of isolating *Brucella* and the characteristic differences of the three species, and there are lengthy sections on brucellosis in human beings and in animals, and on laboratory diagnosis. The final chapter is on the eradication or control of sources of brucellosis infection. Typical case histories are given in an appendix and the volume concludes with a bibliography of 485 titles and an index.

THE EPIDEMIOLOGY OF "HUMAN" BACILLUS TUBERCULOSIS IN THE HUMAN (1941). *Installments Ten and Eleven. The Bulletin of the British Columbia Board of Health, Volume 13, No. 3. Installment Twelve (Conclusion), Volume 13, No. 5.*

By Hibbert Winslow Hill. British Columbia Board of Health, Victoria, B. C. $1.00 each. 11 x 8½; No. 3, 48; No. 5, 83; 1943 (paper).

The material presented herewith represents the concluding instalments of a study on the epidemiology of human tuberculosis which has been underway for a number of years by the British Columbia Board of Health. The author presents pertinent discussions of the following points: the statistical rôle of the uninvaded negatives of tuberculin surveys, rôle of segregation, alternatives to segregation as causes of the falling P.I.—including loss of virulence, decrease in percentage of non-resistants, the rôle of the size of dose, reinfection, and the exogenous reinfection doctrine—the fatality of "human" bacillus tubercle in humans, the "specific genetic resistance" hypothesis, other ancient and modern hypotheses, the resistant:non-resistant hypothesis, natural selective mating, tubercle waves, natural segregations, racial immunities, incubation period events, dosage of infection, healed lesions, "adolescent" tubercle, subsequent infections, and tuberculin positive reactions and protection.

Never having seen the early instalments of the study, in which the bulk of the project is apparently described and explained in detail, it is obviously impossible for this reviewer properly to evaluate the program. However, it would seem from the material herein presented that these epidemiology studies have proven extremely fruitful and that they are significant steps in the right direction insofar as the solution of the human tuberculosis problem is concerned.

100 MEAT-SAVING RECIPES.

By Ann Roe Robbins. Thomas Y. Crowell Company, New York. $1.00. 8¼ x 5¼; xii + 106; 1943 (paper).

This book contains many excellent combinations using variety meats, fish, cheese, and eggs as the source of protein. As it was written before rationing was extended to cover cheese and butter, some changes would be necessary in the quantities specified.

A table of the ingredients necessary for a given recipe placed at the top of the page would be helpful. For the inexperienced cook more definite quantities of seasonings are indicated.

The index is especially well done.

GROWTH AND DEVELOPMENT *with Special Reference to Domestic Animals. LVI. Research Bulletin 366. The Influence of Dairy Merit, Body Size, and Plane of Nutrition on the Economy of Milk Production,* by Samuel Brody. *LVII. Research Bulletin 367. An Index of Muscular-Work Capacity,* by H. H. Kibler and Samuel Brody. *LVIII. Research Bulletin 368. Resting Energy Metabolism and Pulmonary Ventilation in Growing Horses,* by Samuel Brody, H. H. Kibler, and E. A. Trowbridge.

University of Missouri, Columbia, Missouri. 9 x 6; LVI, 31; LVII, 20; LVIII, 14; 1943 (paper).

BIOCHEMISTRY

AN INTRODUCTION TO BIOPHYSICS.

By Otto Stuhlman. John Wiley and Sons, New York; Chapman and Hall, London. $4.00. 9 x 5¾; vii + 375; 1943.

The appearance of a new book on biophysics is certain to arouse widespread interest on the part of biologists and physicists. Stuhlman's *Biophysics,* even before publication, has already done this. One may therefor inquire into the basis for the interest and to what extent this is satisfied.

At the outset, it is essential that one understand what is meant by the term "biophysics." Stuhlman, in his preface, says "Which topics are representative of an ideal cross section of the available biophysical material is at present a debatable question." This may be to some extent true, but it hardly seems to justify the omission by the author of many topics which are commonly regarded as important in biophysics.

To most people, it seems that the natural aim of biophysics is to provide an understanding of the way in which fundamental biological phenomena occur, with special reference to the mechanisms involved. How do chromosomes reproduce themselves, why do they coil, and what is the basis for their external mechanics? What is responsible for cell differentiation, protoplasmic streaming, and cell division? What parts do permeability, diffusion, and convection play in cell respiration? What is the structure of the cell membrane and of its other parts, and what is the structure of larger units such as viruses, bacteriophages, etc.? What is the mechanism of nerve conduction and what is responsible for rhythmic activity? How does a muscle fibre contract and afterwards return to its original length? What is the mechanism of growth and how may life be prolonged? Here, then, is a set of problems which face the biophysicist, and it should be his function to develop methods, both experimental and theoretical, for their solution.

The preface continues: "In order to avoid the imputation of superficiality . . ., only such subjects are discussed as are representative of the major subdivisions of physics." The reviewer feels that the emphasis has been sadly misplaced, that the physics employed must be adapted to the biological problems, and not the problems to the physics. Indeed, a large part of the book reads as if it were a catalog of certain physical apparatus. The style is somewhat loose-jointed, and observations are set down in sequence, with no apparent attempt to unify them. The text suffers from such Brownian motion on p. 33 and p. 97; the Duboscq colorimeter, the barrier-layer photocell, and the hemoglobinometer are all introduced abruptly; a discontinuous transition is then made to absorption of ultraviolet radiation by proteins; the treatment of molecular absorption bands suddenly enters the picture and as suddenly disappears; and the stalagmometer and suspended ring methods of measuring surface tension also come in abruptly.

The effects of X-rays, γ-rays, and ultraviolet light are discussed in Chapters I, II, and IV, respectively. Chapter II deals with the eye and with color vision, Chapter V with surface tension, osmotic pressure, and permeability, Chapter VI with nerve conduction and brain waves, Chapter VII with the anatomy and mechanical properties of the ear, and Chapter VIII with the compound microscope and electron microscope.

Many subjects which would normally be expected in a book such as this are omitted. It is assumed in places that the reader is more familiar with atomic physics than can reasonably be expected of the average biologist (e.g. p. 10, K, L, M electrons are discussed with no introduction). The treatment of a cell (p. 35) is extremely sketchy, and there is no reference either to the work of Timofeeff-Ressovsky on mutations by X-rays, nor to that of Sax on chromosome breaks. (The statement, p. 35, that genetic changes occur in direct proportion to the dose of radiation is incorrect for it does not apply to inversions or any other changes requiring more than one hit.) Not mentioned are: the betatron as a source of radiation, the effects of protons and neutrons, the work of F. O. Schmitt on

ultrastructure (by using X-rays and polarized light), the suggestions of Davson and Danielli concerning the structure of the cell membrane, the researches of Cole on the nerve impulse, the work of Arvanitaki on rhythmic activity, local response, hearing aids and bone conduction, present limitations of the electron microscope as regards biological specimens, electron microscope pictures of viruses, bacteriophages, collagen and hemocyanin, and the work of Hill and others on muscle.

In three specific instances, the organization of the book could be improved by rearrangement. It would, in the reviewer's opinion, be better to give at least part of the Compton effect discussion (p. 23) on p. 14 or earlier. The treatment of ionization (p. 38) also seems to come quite late. Absorption is discussed once for X-rays (p. 16) and once for light (p. 144).

There are many cases where statements are made which are either vague or tautological. On p. 71, it is stated that γ-rays lose energy by true absorption (photoelectric effect) and by scattering (Compton effect). Pair production is ignored. In Table II-7, the wave length of the γ-rays is not given. On p. 85, there is no explanation of the "typical biophysical sigmoid-shaped response curve." On p. 117, there is no explanation of the luminosity curve for individual observers, nor any mention of its variation with physiological condition, nor of the distinction between it and the *standard* luminosity curve.

On p. 164, the following passage occurs: "... let us consider a molecule of hydrochloric acid in which the hydrogen and chlorine atoms are a definite distance apart. This molecule, by acquiring additional energy through absorption, can respond (so that) there may result a vibration...." The molecule will vibrate even in its ground state (zero-point energy). The Franck-Condon principle is not mentioned, and potential energy curves would be helpful if this section is to be included at all.

There are a few errors which have been noted. On p. 11, it is stated in the text that the L series lines (rather than the M series) have wave length $\lambda = 6.9A°$. On p. 13, Avogadro's number is given as 6.06×10^{22}, whereas in the Appendix it is 6.0228×10^{22}. The work of Curie-Joliot (p. 88) was prior to that of Chadwick (see Darrow *Contemporary Physics* for the detailed history). On p. 103, there is either a vagueness or an error, for 35°C is mentioned here and 25°C on p. 104. This list is to be regarded as a sample, and is not exhaustive.

In conclusion, the author has written a book which emphasizes physical apparatus and physical methods rather than problems of current interest in biology. It will be of use to those, among others, who wish to know how to protect themselves from radiation, to those interested in the mechanisms of the eye and ear, and to those who want to know about optical and electron microscopes. It does not satisfy the needs for understanding mentioned at the beginning of this review, and consequently is not very suitable as a textbook for students of a biophysics course which has that for its purpose.

DICTIONARY OF BIO-CHEMISTRY AND RELATED SUBJECTS.

Edited by William Marias Malisoff. Philosophical Library, Inc., New York. $7.50. $8\frac{1}{8} \times 5\frac{1}{8}$; 579; 1943.

Although the title of this book is *Dictionary of Biochemistry* it is not a dictionary in the common sense of the term. In addition to terms treated merely with a definition or a short description, many items are covered in more encyclopedic form. These longer discussions frequently take the form of very condensed review articles, briefly outlining the topic under discussion and pointing out problems still to be solved. References are also given for the various tests and reactions cited.

The subjects covered range all the way from strictly anatomical definitions to statements of the perfect gas laws, and as might be expected under such an arrangement, few fields are exhaustively treated. Probably the worst failing in this respect is the frequent discussion or definition of entries in terms of other substances or reactions which are not themselves included. In general the treatment is more from the biological and medical points of view than the chemical. This is emphasized by the fact that while therapeutic values and clinical uses are often discussed, structural formulae are rarely given. The medical emphasis seems to be particularly unfortunate. The book cannot hope to compete with established medical dictionaries and the space devoted to medical topics and terminology could well be utilized for items not covered by strictly medical works.

The exact rôle which this book will come to play in the libraries of biologists and chemists can only be decided with time, but it does provide a great deal of diversified information compiled by a large number of eminent scientists. This information is in readily available form, and, in spite of its many shortcomings, the book should prove a useful addition to the reference shelves of biological laboratories and research institutions. With succeeding editions probably many of the initial faults can be ironed out.

THE CHEMISTRY OF NATURAL COLORING MATTERS. *The Constitutions, Properties, and Biological Relations of the Important Natural Pigments.*

By Fritz Mayer. Translated and Revised by A. H. Cook. Reinhold Publishing Corporation, New York. $10.00. 9 x 6; 354; 1943.

The past two decades have seen a rapid increase in our

knowledge of the occurrence, properties, and chemical structures of natural coloring matters. As a result, most of our information on the carotenoids and porphyrins as well as on the less completely studied pterins has accumulated during a period in which no really comprehensive effort has been made to bring this accumulated information together. The author of the present volume has undertaken this tremendous task with truly gratifying results.

The subject matter is divided into five chapters: Carotenoids (polyene pigments), Diaroylmethane compounds, Carbocyclic compounds, Heterocyclic compounds (compounds containing heterocyclic oxygen atoms), and Compounds containing heterocyclic nitrogen atoms. The second chapter on diaroylmethane compounds is very short as curcumin is still the only natural pigment known to belong to this group. The material is presented very compactly and includes reference to the occurrence of the pigment, brief historical notes, and where the information is available, its physical properties, reactions, structural formula, and synthesis. The discussions vary greatly in length depending largely upon the extent to which the chemistry of a given pigment has been elucidated. Details are usually omitted, but the over 1000 footnote references provide abundant source material for anyone interested in investigating a particular subject more thoroughly. The author often digresses from the strictly chemical aspects of his subject to discuss the biological significance of various compounds. This is particularly noted in the case of echinochrome, crocetin, and similar chemotactic substances, but other biological properties are frequently mentioned. Reference is also made to the uses of various pigments and their derivatives.

This is a well-written, comprehensive and thoroughly authoritative book which should be of value to anyone interested in natural pigments. Biologists may be somewhat surprised to find the biologically important melanin pigments omitted, but our extremely limited knowledge of the chemistry of these compounds may perhaps justify their exclusion. In addition to the over 1000 footnote references mentioned above, the book contains a short list of general references, and extensive subject and author indexes. It has been revised by the junior author to include material published up to the summer of 1941.

INTRODUCTION TO ORGANIC AND BIOLOGICAL CHEMISTRY.

By L. Earle Arnow and Henry C. Reitz. C. V. Mosby Company, St. Louis. $4.25. 8½ x 5¾; 736; 1943.

In view of the fact that no other single textbook covering the two separate fields of organic chemistry and biological chemistry has appeared on the market, this excellent volume fulfills a real need.

The subject matter of the text has been drawn, as largely as possible, from materials familiar to everyday life, and is presented in relation to the many recent commercial products and processes which are exerting a tremendous influence on man's present social economy. Students training for medicine, dentistry, dietetics, agriculture, home economics, and physical education, as well as pure chemistry, will find this text well suited to their several needs.

The work is divided into three broad sections. The first is an elementary review of the fundamentals of general chemistry, and is designed to orient the student who may have been away from the subject for some time prior to his enrollment in a course of organic chemistry. The second section covers the materials and methods of organic chemistry, and presents detailed discussions on such timely topics as plastics, explosives, synthetic rubber, and a variety of petrolium products, from the standpoint of the organic compounds to which they are related, or from which they are derived. The third, and unique section of the book, presents the subject of organic chemistry as related to the various physiological processes of living organisms. The discussions cover the enzymes, hormones, vitamins, and the metabolism of various products of digestion, as well as the chemistry of respiration. The illustrative materials, the "eye-tone" paper, and the general neat appearance of the volume are factors which will add to the interest, the value, and the popularity of the text in the field of organic chemistry.

Tables on International Atomic Weights, and the composition and caloric value of foods are appended. Indices by author and topic are provided.

THE RELATION OF HORMONES TO DEVELOPMENT. *Cold Spring Harbor Symposium on Quantitative Biology. Volume X.*

The Biological Laboratory, Cold Spring Harbor, New York. $4.50. 10¾ x 7¾; xi + 165; 1942.

In this series of eighteen papers, the problem of the relation of hormones to development has been attacked from many angles, varing from the chemistry of the hormones, and the influence of hormones on atypical growths, to the hormonal control of development in a wide variety of plants and animals. The two introductory papers, by George S. Avery and Oscar Riddle, set the pace with respect to the scope of the problem of the endocrines in relation to growth and development, and the complexity of the picture is not minimized by any of the succeeding papers. Beyond the two introductory papers, there is no logical order of presentation by subject matter; the papers are simply ordered alphabetically by name of author.

Of particular significance is the paper by Bodenstein on the influence of hormones on insect growth and

metamorphosis. Here the recent literature is reviewed briefly, yet clearly, and the status of the subject brought up to date. It is evident from recent studies, that the processes of growth and metamorphosis in insects are distinctly separate and that each is influenced by a different hormone. This phenomenon permits a more direct attack on the relation of hormone action to tissue proliferation than is probably offered by any other organism.

The work on sex hormones in unicellular organisms by Sonneborn is also of unusual interest in that it discuses the isolation of a diffusible sex substance in Protozoa which provides a very favorable opportunity for the study of such a sex substance (hormone) on both the development and the genetics of unicellular organisms.

Each paper contributes a wealth of illustrative and bibliographic material and the complete volume is carefully indexed.

ELEMENTS OF FOOD BIOCHEMISTRY.

By William H. Peterson, John T. Skinner and Frank M. Strong. Prentice-Hall, Inc., New York. $3.00. 9 x 6; xii + 291; 1943.

The purpose of this book is to emphasize the chemistry of the constituents of food and the chemical changes that these constituents undergo in the process of metabolism. As far as possible, important chemical compounds and changes have been expressed in terms of formulas and equations, not because students are expected to reproduce all of them, but because the authors believe that the chemistry concerned can be most accurately expressed by such formulation. Some teachers can be expected to question the advisability of including in an undergraduate text a formulation and discussion of the intermediary metabolism of carbohydrates, but the authors maintain that there are sufficient well-established facts in this field to warrant presentation here. The material has been collected during more than thirty years of teaching the subject. Three previous editions have been issued in photographic offset form and have been used for about twenty years at the University of Wisconsin.

Subject-matter is presented in the following order: carbohydrates, fermentation food products, acidity, lipides, proteins, the mineral elements in nutrition, water, vitamins, and enzymes. The numerous illustrations have been carefully selected for their teaching value, and the volume is richly supplied with various tabular matter. Review questions, lists of references, and suggested readings are placed at the end of each chapter. The appendix contains information concerning the approximate composition of foods, percentages of the major mineral elements and trace elements in the edible portion of foods, and the vitamin content of common foods—containing data for several of the newly-discovered B vitamins not previously compiled in any convenient form. A complete index concludes this well-written text.

THE THEORY AND PRACTICE OF SEMIMICRO QUALITATIVE ANALYSIS.

By G. B. Heisig. W. B. Saunders Company, Philadelphia and London. $2.50. 8¾ x 5½; x + 331; 1943.

The teacher of qualitative analysis will find the present volume an excellently planned text. The material "is presented in the light of the theory of ionization, the law of mass action and the concepts of Debeye, Brønsted and Werner." It is planned to serve as a basis for two quarters of five credits each, of qualitative analysis, but is so divided that the analysis of cations can be used alone when only one term of qualitative analysis is taught. The author has provided many preliminary experiments so that each instructor can select those most suited to the needs of his students. The size of the sample used for the analysis has been reduced to 1 mg., since it has been found that the smaller sample has many advantages in laboratory technique.

In the first part of the volume the theory of qualitative analysis is discussed. At the end of each chapter is given a series of exercises. In some cases the answers to the problems are provided so that the student can check his work. Part II is concerned with the systematic analysis of cations and anions. Exercises are also given at the end of each chapter. In an appendix much additional useful information is listed concerning equilibrium constants, oxidation-reduction potentials, mathematical operations used in qualitative analysis, reagents, stock solutions, equipment, and tables of common logarithms. A list of reference books on qualitative analysis and general inorganic chemistry is also given.

VITAMIN VALUES OF FOODS. *A Compilation.*

By Lela E. Booher, Eva R. Hortzler and Elizabeth M. Hewston. Chemical Publishing Company, Brooklyn. $2.75. 8¾ x 5⅜; 244; 1942.

The authors have summarized the available data on the vitamin content of foods in relation to variety of plant or breed of animal, method of cultivation or feeding practice, place of production or source of material, method of cooking, processing, storage, variations in degree of maturity, and method of analysis, insofar as such information could be obtained from original published reports. Methods of analysis for several of the recognized vitamins have not as yet been established, although very promising methods are gradually being developed. The tabulated vitamin values include only

those values that were determined in terms of absolute weights of the vitamins or directly in terms of International Units. Vitamin values recorded only in graphs were not included because of the inaccuracies inherent in ascertaining the precise figures. The recorded values for the Vitamin A, thiamin, ascorbic acid, Vitamin D, and riboflavin contents of foods are listed. Tables are used throughout the entire book to list the vitamin contents of the various food products. First column of the tables contains an alphabetized classification of the foods for which some one or more vitamin values were obtainable. As far as possible, the source of the sample analyzed by the original investigator and the general method of analysis also have been recorded under the heading "Description of samples." Quite an extended list of American and foreign publications were consulted by the authors in the preparation of the present volume and it is quite obvious from the organization of the material that every effort has been made to insure the correctness of the data. The book concludes with a list of nearly three hundred references. There is no index.

FORMATION IN VITRO OF HIGHLY ACTIVE THYROPROTEINS, THEIR BIOLOGIC ASSAY, AND PRACTICAL USE. *University of Missouri Research Bulletin 355.*

By E. P. Reineke and C. W. Turner. University of Missouri, Columbia. 9 x 6; 88; 1942 (paper).

This bulletin covers the literature as well as a series of original experiments dealing with the biological assay and physiological effects of various thyroid substances and iodinated proteins. Tadpoles and guinea pigs were used for the assay work; their physiological response to a graded series of doses of thyroxine being used as a "yard-stick" for demonstrating the physiological effects of the administration of artificial thyroproteins.

Significant among the findings here reported are: (1) an artificial thyroprotein (iodinated casein) has been produced, in which the thyroidal potency has been shown to be approximately 10 per cent of that of thyroxine when assayed by injection in tadpoles; (2) crystalline thyroxine has been isolated from a barium hydroxide hydrolysate, and has been thoroughly identified with the synthetic product; and (3) artificial thyroproteins have been shown to alleviate the symptoms of cretinism in thyroidectomized goats, and to increase milk production in lactating goats and cows.

Incidental to the main topic under consideration are discussions on a micro-injection apparatus for use with tadpoles, a procedure for the artificial breeding and culture of tadpoles, and a standard technique for the formation of iodinated proteins.

The work is well supplied with tabular and photographic materials and carries a bibliography of some 125 titles.

ADVANCES IN ENZYMOLOGY AND RELATED SUBJECTS OF BIOCHEMISTRY, *Volume III.*

Edited by F. F. Nord and C. H. Werkman. Interscience Publishers, Inc., New York. $5.50. 9 x 5⅞; 406; 1943.

The reception accorded the two earlier volumes in this series (cf. Q.R.B., Sept., 1943) of carefully prepared and authoritative biochemical treatises will doubtless be shared by the present volume. The eleven contributors to Volume III include recognized Swedish, British, Swiss, and American authorities. This newest addition to the series has been dedicated to the memory of Richard Willstätter, the world renowned German chemist and Nobel prizewinner, famous for his synthesis of chlorophyll. Subject matter presented herein includes: chromosomes and nucleoproteins, effects of temperature of enzyme kinetics, X-rays and the stoichiometry of the proteins, the chemistry of glycogen, verdeperoxidase, mechanisms of carbohydrate metabolism, the intermediary stages in the biological oxidation of carbohydrate, the chemistry and biochemistry of pantothenic acid and of biotin, recent progress in tumor enzymology, and the rôle of microorganisms and enzymes in wine making. Appended to each section of the book is its own extensive list of references—a total of over 1300 being given. The tables, charts, graphs, and other illustrative material are well chosen and very helpful. An author index, subject index, and a cumulative index of Volumes I–III conclude the volume, which is well printed and substantially bound.

SEX

MARRIAGE *Before and After.*

By Paul Popenoe. Wilfred Funk, Inc., New York. $2.00. 7¼ x 5; xi + 246; 1943.

A popular common sense account, mostly from the mental hygiene standpoint of personality problems arising in connection with marriage, and of the adjustments important in marriage success. The author uses case "stories" extensively and catches the cursory reader's attention by well chosen phrases and anecdotes. Eighteen chapters, averaging seven pages each, deal with problems of men and women before marriage, and fourteen chapters with those in marriage. While the problems considered are mostly of a psychological nature, some space is given to sex aspects of marriage and to sterility. Occasionally, the common sense and sincerity of the author laps into doubtful pragmatic advice, as in the fifteen suggestions made in the chapter, "Why don't you make him propose," or in paragraphs with a beginning sentence such as, "Plan your campaign intelligently." Nevertheless, the reviewer must admit of having received some useful hints in various parts of the book! A bibliography is lacking in spite of repeated general references to "any large library" for clarifying one's thoughts.

BIOMETRY

THE CANADIAN BORN IN THE UNITED STATES. *An Analysis of the Statistics of the Canadian Element in the Population of the United States, 1850 to 1930.*

By Leon E. Truesdell. Yale University Press, New Haven; The Ryerson Press, Toronto. $3.00. 9⅝ x 6½; xvi + 263; 1943.

This book is one of a series of three dealing with the relations of Canada and the United States, prepared under the direction of the Carnegie Endowment For International Peace, Division of Economics and History. One of these volumes, *The Mingling of the Canadian and American Peoples*, by Marcus Lee Hansen, gives an historian's approach to the subject. The other two are analyses of the official statistics from 1850 to 1930, the one under review dealing with facts from the United States censuses on the Canadian element in this country. The companion volume, *The American Born in Canada*, by R. H. Coats and M. L. MacLean, has for its source data those from the Canadian censuses.

Dr. Truesdell, Chief Statistician for Population in the United States Bureau of the Census, has brought together in the present volume a large amount of data which is arranged in 121 tables and 36 maps and diagrams. This material is broad in scope, describing our Canadian population as to color, age, sex, racial stock, ability to speak English, home ownership, size of family, and occupation. Throughout, the tabulations are given separately for the French and the English Canadians. For many of the variables, time changes are shown, as well as the situation for the different parts of the country. The text accompanying the tables points out the salient features, and a summary, contained in the first chapter, orients the reader who finds table-reading forbidding.

For the reader who enjoys delving into the facts on the make-up of our population, on how and where the French Canadians live as compared with the English, on how much they earn and what languages they speak, there is a large array of interesting material.

It is, however, the student of population and of social trends who will especially appreciate the presentation of this material in a single volume. The facts on the migration of these population groups, now assembled from a long series of census volumes and special reports, offer opportunities for further study and interpretation.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 5, Number 4, December, 1943.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: A Logical Calculus of the Ideas Immanent in Nervous Activity, by Warren S. McCulloch and Walter Pitts; A Statistical Consequence of the Logical Calculus of Nervous Nets, by H. D. Landahl, W. S. McCulloch and Walter Pitts; A Mathematical Theory of the Affective Psychoses, by Jerome Y. Lettvin and Walter Pitts; On Synchronous Sporulation with Possible Reference to Malarial Parasites, by Alston S. Householder; A Theory of the Induced Size Effect, by Alston S. Householder; Note on Rashevsky's Equation for Cellular Growth, by Alston S. Householder; On the Origin of Life, by N. Rashevsky.

PSYCHOLOGY AND BEHAVIOR

SURVEY OF OBJECTIVE STUDIES OF PSYCHOANALYTIC CONCEPTS. *A Report Prepared for the Committee on Social Adjustment. Bulletin 51.*

By Robert R. Sears. Social Science Research Council, New York. $1.50. 9 x 6; xi + 156; 1943 (paper).

This is a report prepared for the Committee on Social Adjustment of the Social Science Research Council by Robert R. Sears, concerning the contributions of non-psychoanalytic literature on the basic validity of certain important Freudian concepts. The chapter headings will indicate the fields which were investigated from this standpoint, namely, erotogenesis, erotic behavior of children, object choice, distortions of sexuality, fixation and regression, repression, projection and dreams.

Sears has combed the important literature, and as is to be expected, the pertinent contributions consist of statistical studies of large samples and of results of experimental procedures both on animals and on the human. He points out that these methods in large measure assess human behavior very often with little attention to their dependence on the basic items in analytic method and conception, namely, verbalization and subjective emotional status. His conclusions are important and may be summarized as follows:

Few non-analytic investigators "feel free to accept Freud's statements at face value." This depends essentially upon the fact that analysis relies on non-objective techniques which may not interfere with therapy, but which do not fulfill the criteria of "good science." In general it may be said that the investigations in part confirm, sometimes amplify Freud's discoveries, sometimes deny them. Very often where there is support for Freud's contentions, it has been shown that Freud's assumption that these items were of universal import is not supported. This may be because Freud's discoveries were made on special samples of personalities, or because other methods of investigation reach a different kind of material.

Specifically, the following items are worth mentioning. Freud's conception of infantile sexuality is rather well supported in that the oral and anal urethral erotic zones have been established. There is no data on the degree to which this erotogeneity is native. There is some evidence that practice, and the feeling of gratifica-

tion increase the strength of the drive. There is no evidence to confirm Freud's assumption about the interrelationship between the various erotogenetic zones, or whether one zone can satisfactorily substitute for another.

Sexual behavior in childhood has been shown to be exceedingly common, and the reactions of guilt and fear to pregenital impulses are quite the same as to genital impulses. Castration complex is not common. Children generally show little tendency toward fears or curiosity about the sexual process when sex information has been adequate. "It seems probable that Freud's notions about children's attitudes toward sex were based on a small sample that was far from characteristic of contemporary American children."

Concerning the Oedipus situation, Sears concludes that there is no universality of this in the least, that children are deeply influenced by the family situation, but that each family situation is to some extent unique. In other words there are family situations which more or less confirm the Freudian Oedipus doctrine, but this is only one variety of family situation and childhood sexuality development. It may be concluded that Freud's description of sexual development is inaccurate and incomplete.

Concerning fixation and regression, non-analytic studies have made their most important contributions clarifying the rôle of the learning process. It is in this field that experimentation has been most successful. Freud's supposition that strong habit fixation is the essential prerequisite for regression was verified by experimental studies on rats. Nevertheless it has been shown that frustration is only one of the several factors which initiate the regressive phenomena. Two other such precipitating factors are satiation and alcohol. The most important item here is that fixation and regression are elements in the learning process.

Concerning the mental mechanisms described by Freud, non-analytic studies throw very little light and certainly no additional light. The material in the differential recallability for gratifying and anxiety-inducing experiences is of considerable importance, and this has been demonstrated by non-analytic methods, crude as they are. This chapter has not been more adequately examined by non-analytic methods because the material of this field depends upon language, verbal report, and on strong emotions. The former cannot be studied in animals, and the latter cannot safely be studied experimentally in man. "It appears that until some new conceptual organization of facts can be devised, progress in their investigation by non-analytic techniques must be slow."

Sears concludes with an interesting statement concerning the directions of progress. He views psychoanalysis as a science of personality applicable to education and to therapy. So far it has been better applicable to the latter than to the former. Education has benefitted more from a personality science based upon behavior rather than experience. He looks to the growth of science of behavior personality based on those influences loosely defined as growth, learning and social milieu. Nevertheless psychoanalysis is something which cannot be disposed of, and its insistence on the experiential core of personality needs to be incorporated into the behavior system through additional longitudinal studies of personality development, studies of the records obtained year after year from the same children.

In addition the studies of object fixation need further expansion, and this could be done without any great waste in present techniques. Also cross cultural comparisons of personality development can assist in evaluating the effect of the social milieu as a source of motivational and trait characteristics. This is an appeal to ethnological and anthropological field work and extension of concepts to individual personality development.

CHILD BEHAVIOR AND DEVELOPMENT. *A Course of Representative Studies.*

Edited by Roger G. Barker, Jacob S. Kounin and Herbert F. Wright. McGraw-Hill Book Company, New York. $4.00. 9 x 6; viii + 652; 1943.

This is a very valuable book which aims to provide foundation material and work in child psychology for the use of college students. It consists of selections of important contributions, from periodic literature in numerous aspects of child behavior and development, to give a very well-rounded picture of methods of study and the results of specific studies from several schools of thought. The general plan is admirably presented in Lawrence K. Frank's opening chapter, "Research in child psychology: History and prospect." He shows how child behavior studies began with naturalistic studies, biographies. Then the predelictions of psychology intruded themselves, with the predominant search for quantitative objective methods and resulting specific items of behavior as exemplified in the Binet-Simon test, based on statistical methods. Coincident with this was a growing skepticism concerning the significance of the statistical facts as applied to individual cases and the clear need for more elasticity in the use of the material. Significant in this respect were the contributions of anatomy and pediatrics, particularly the x-ray studies of T. Wingate Todd, which showed the remarkable variations in bony growth of children of like ages. Then there came the influence of the child guidance clinics with a clinical approach and the emphasis on emotional factors which defy quantitative examination.

In a sense, therefore, there began to develop a split between those who continued to construct, elaborate, and define standardized tests through the manipulation of the data obtained from children they rarely if ever saw, and the clinical psychologists who examine specific

individual children for diagnostic and remedial purposes, as for counselling and guidance.

A persistent concern of the child behavior movement has been the endeavor to distinguish between the influence of nature and nurture.

The upshot of all this in general terms is that child growth and development follows an orderly process, but that this process doesn't produce of necessity standardized dimensions at any given time. Present trends look to the importance of longitudinal studies of child development with a growing appreciation of the importance of time, and to the study of the effects of culture on the individual personality.

This excellent summary of the past, present, and future prospects of the child development field is followed by some thirty-four chapters, each a beautiful piece of investigation of a special field, and illustrating all the points mentioned in Frank's introduction. To mention only a few: Reflex activities in the human fetus, by Davenport Hooker; Language development in the preschool child, by Dorothea McCarthy; The Stanford Binet scales for measuring intelligence, by Lewis M. Terman and Maud A. Merrill; Intellectual development and rigidity, by Jacob S. Koumin; Learning and maturation in identical infant twins, by Arnold Gesell and Helen Thompson; Study of personality development, by Jean Walker Macfarlane; Studies of children's fears, by Arthur T. Jersild; The effect of barriers upon strength of motivation, by Herbert F. Wright; Frustration and regression, by Roger G. Barker, Tamara Dembo, and Kurt Lewin; Social behavior of preschool children, by Mildred Parten and S. M. Newhall; The Hopi child, by Wayne Dennis.

It is a good thing to have brought together in one volume so many fundamental and excellently presented topics. It is not stated how much previous training in psychology would be desirable before the work presented in this volume could be digested with profit. It is pretty clear, however, that a considerable all 'round background would be necessary in order to follow and make the most out of some of these studies.

NEW HORIZONS IN CRIMINOLOGY. *The American Crime Problem.*

By Harry Elmer Barnes and Negley K. Teeters. Foreword by Frank Tannenbaum. Prentice-Hall Inc., New York. $6.00. 9 x 6; xxvi + 1069; 1943.

This book is offered as a "comprehensive treatment of crime, criminals, punishment, and prisons," and as supplying "the basis for suggestions as to desirable future reforms in the repression of crime and the treatment of criminals."

To this reviewer it handsomely fulfills its promises. The authors pass in review the history of criminology, and show its three phases based on the views of crime as (1) a contravention of the authority of the gods; (2) an affront to the majesty of the state (itself derived from the gods); and (3) as "any act which the (social) group regards as sufficiently menacing to warrant a decisive group reaction to condemn and to restrain the offender of such an act."

The last named view, rationalistic, modern, and employing the general viewpoints of sociology, psychology, and psychiatry, is seriously compromised by residuals of the other two views resident in the popular psychology, the laws, the personal biases of judges and juries, and the whole prison system with its dual punishment and reform motifs.

Sober thought concludes that the prison systems of today, modified as they have been with graftings of scientific and humane methods, exact a terrible toll in human suffering and in the prolific breeding of more crime for the social gain through the mere fact of detention.

The authors trace the rise of the prison system fully. Modern methods rest on a compromise between the Pennsylvania system of isolation and quiet and the Auburn (New York) system of congregation and quiet, and on the more recent reformatory idea started in Elmira, New York.

The authors reach only one conclusion—that the whole prison system must go—since it does more harm than good. With it must go the jury trial system, as well as the punitive motives in the laws.

They call for individual case work much in the manner of psychiatric social service set-ups, the indeterminate sentence arrived at by groups of experts, the use of parole to trained personnel, and the more extensive use of psychiatric hospital for the mentally abnormal. Detention with an opportunity to become self-supporting is to be reserved only for hardened habitual criminals for whom the other methods are not applicable.

The relativity of the nature of crime is stressed, and there are enlightening chapters on "white-collar" crime, and suggestive paragraphs dealing with certain aspects of the conduct of the war, or the obstruction thereof, certain modern big business and labor racketeer methods. These get into aspects of the social life in which the pragmatic definition of crime as given above may or may not be generally accepted.

The book is exceedingly informative and provocative. The reviewer, a psychiatrist, stands a bit embarrassed at the expectations the authors entertain for the usefulness of his profession in this realm. No psychiatrist could do anything but agree with the authors, and all would welcome criminology to the congregation of scientific disciplines—but all will do well to express humility before the task. The authors' call for an objective study and evaluation of the problem free from old prejudices sounds like an echo from the all too recent past in psychiatry also. Nor can the latter discipline call itself freed as yet. The inheritance—intellectual

and emotional—from the dark ages is still the established currency on the "gold" basis of right and wrong. The authors make a forceful argument for and appeal to a more realistic social basis of what *works* and what does *not work* in the field.

MIND, MEDICINE, AND MAN.

By Gregory Zilboorg. With a Foreword by Arthur H. Ruggles. Harcourt, Brace and Company, New York. $3.50. 8½ x 5⅝; vi + 344; 1943.

Zilboorg has given to the laymen in this book a magnificent exposition of the development of modern psychiatry—its relationship to sociology, economics, criminology, and to religion. The presentation follows the Freudian pattern, and the author proves himself again a provocative and seductive champion of psychoanalysis. What he has to say concerning the workings of the "mind" should be read by every layman but also by every doctor. The author's views of personality functions should appeal to physicians who have too long harbored poorly defined conceptions concerning this problem.

The first half of the book, taken up with laying a host of popular misconceptions concerning the topics of mind, and to the Freudian groundwork in theory and practice, is followed by several chapters dealing in general with the impact of psychoanalytic thought on anthropology, sociology, economics to a lesser extent, and on criminology. The chapter on criminology is a most severe indictment of the law's methods and outlook, but a dignified indictment and a plea for collaboration with psychiatry.

The chapter headed psyche, soul, and religion sees Zilboorg for the first time differing with Freud concerning the relationships of psychoanalysis and religion. It is a most provocative chapter, ending with a plea for further study of the question. It is only in this chapter that the author rather frankly allows himself to delve into the philosophy of relationships of all those disciplines loosely grouped together as anthropological. Thoughtful people will approve his practical assertion that religion cannot be ignored as "unscientific" and that since faith is a fact of human living it must be studied for all it may be worth.

This reviewer finds himself doing what Ruggles in his foreword predicted, namely, feeling that the author was too positive and self-assured in his attempt to settle certain popular misconceptions concerning the human mind—Zilboorg may have set up some new misconceptions of his own! This did not detract from his appreciation of this book as a most valuable statement of the topic, which could be read profitably by every psychiatrist as well as layman, if for no better reason than its lucid and critical statement of the development of psychoanalysis. The author uses language in a masterly fashion and has proven himself again a powerful figure in the psychoanalytic world.

BEHAVIOR AND NEUROSIS. *An Experimental Psychoanalytic Approach to Psychobiologic Principles. By Jules H. Masserman. University of Chicago Press, Chicago.* $3.00. 9½ x 6¼; xv + 269; 1943.

The subtitle of this book is misleading. It should read: "An investigation into the analogies of Pavlovian, Freudian, and general behavioristic tenets." It is no more than that. The book begins with the records of the Pavlovian experiments of the author—well conceived, well stated. These include the establishment and "cure" of experimental "neuroses" in cats.

There follows a review of the literature on the experimental study of behavior and of neurosis, followed then by the clinical and therapeutic applications.

He comes to the conclusion that cats, like humans, apparently do not thrive with conflict, and that under such situations they both develop peculiar modifications of behavior (erroneously) labelled neurosis in each instance. Further, that these behavior anomalies are reducible through "diminution of the intensity of one of the conflictful drives"; "reassurance"; "persuasion and suggestion"; "environmental press"; "social example"; and "working through."

He concludes that behavior rests on four general principles:

1. It is motivated by the biological needs of the organism.

2. It is contingent upon, and adaptive to, the *meanings* of the "objective" social environment as interpreted by the individual organism.

3. It relieves bodily tensions not only by direct, but also by *substitutive* or *symbolic* activity.

4. When psychobiologic motivations or environmental meanings become excessively confused or conflictful, behavior correspondingly becomes indecisive, substitutive, diffusely symbolic, and biologically inefficient, i.e. "neurotic" or "psychotic" in expression.

Some readers may agree with Alexander's enthusiasm for the book. Others will share Adolf Meyer's attitude calling for all the stimulation possible from the various disciplines, and looking for their convergences. The author's reproach for Meyer's "aloof juridicism" leaves the reviewer unconvinced that a fusion has occurred. There may be convergences, yes, but analogy is not fusion.

AN INTRODUCTION TO GROUP THERAPY.

By S. R. Slavson. The Commonwealth Fund, New York. $2.00. 9 x 5¼; xvi + 352; 1943.

Group therapy has been employed at the Jewish Board of Guardians in New York City since 1934. Material

herein presented is based upon the detailed records of some 750 children and 55 groups, each of which functioned for about two years. The records included follow-up studies of clients as to their adjustment in home, school, unorganized play group, and organized recreational activities. Out of this extensive experience has come an understanding of the principles underlying Group Therapy, which is not merely group activity, but a method of psychotherapy to be employed along with psychiatric case work and psychological services, and only after a diagnostic examination indicates that it is really needed. This thoughtful discussion indicates when, with whom, for what purposes, and how Group Therapy may be properly used. The author presents typical Group Therapy cases, and gives outlines for referral summary, progress report, integration conference, and follow-up study. The author emphasizes that Group Therapy cannot be considered a substitute for other types of psychotherapy, and that while it can be assumed that recreation and group interaction are desirable and important to everyone, Group Therapy has value for children with special needs. Another fact to bear in mind is that Group Therapy, being a method of psychotherapy, can be carried on only in an agency or clinic where psychiatric services are available for diagnostic purposes as well as for consultation and treatment. The present volume is intended to formulate some of the basic principles of interpersonal therapy and to outline the practice of Group Therapy.

Chapter headings include the following: Principles and practice of Group Therapy; Two records of group meetings; The choice of clientele; The problem of the group; The function of the adult; The therapeutic process; Five typical cases; and Variations in group treatment. The appendix contains outlines for the use of Group Therapy workers and a list of terms and phrases used in this type of psychotherapy. References are given in the form of footnotes. There is an excellent general index.

PSYCHOLOGY YOU CAN USE.

By William H. Roberts. Harcourt, Brace and Company, New York. $2.00. 8 x 5¼; 246; 1943.

To many people the word "psychology" suggests tests and measurements and scientific laboratories. But the word actually means the science of behavior and experience, and some understanding of it might well be a part in everyone's mental equipment. Tests are important in the work of psychologists. Some interesting and amusing ones are described in this book. But this is not a book for psychologists. It is the story of their work and what they have accomplished in explaining how human beings get the way they are.

The average citizen knows little and cares less about the scientific definition of an I.Q., or a reflex, or a stimulus. But when the science is brought down to actual everyday experiences it is a different matter. Why, for instance, will nine out of ten people who read this volume fail to notice several of the misprints purposefully included in one chapter? Why do you jump when you are startled by a sudden sound? Do you remember best things you have seen, or heard, or touched, and why? How can psychology help you to overcome difficulties and get along with other people? These are just a few of the questions which the author answers in this book.

The discussion suffers a trifle at times due to the oversimplification of the material, but this can hardly be called a serious shortcoming. The volume is provided with a complete index, but there is no bibliography.

GETTING THERE. *The Psychomotivatease.*

By Robert M. Yergason. Mrs. A. R. C. Yergason, West Hartford, Connecticut. $1.00. 8½ x 5½; 39; 1943 (paper).

Amusing descriptions, in rhyme, of the manner in which animals, from unicellular forms to man, manage to move about. Appropriate pen and ink sketches by the author accompany the text.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

PHYSICS AND PHILOSOPHY.

Sir James Jeans. Cambridge: At the University Press; The Macmillan Company, New York. $2.75. 8½ x 5⅝; vii + 222; 1943.

Some years ago one of the leading literary magazines published a story about a man who numbered numerous devotees of philosophy among his friends. These couched their conversation in such metaphysical jargon that he seldom had any very clear idea as to about what they were talking. This man's reaction was to take up the study of the pipe organ, not because he enjoyed making music but because it enriched his vocabulary and enabled him to ornament his conversation with esoteric phrases that were designed to impress his hearers with his erudition and so serve as a defense mechanism.

The present reviewer must confess to a great deal of sympathy with the hero (or the victim) of this story whenever he reads a modern philosophical treatise, except when (as happens in the present case) the author is a scientist who indulges in philosophical ruminations as a restful contrast to his scientific activities. Dr. Jeans disclaims being a philosopher. Certainly he does not write like one. As one of the world's leading scientific intellects he seems to be too many light years

away for us to follow him when he discusses the red shift in the spectrum, or the exploding universe, or the equation that tells us about pq-qp, but when he dips into philosophy he does not dip so deeply that we cannot dip with him and share his thoughts. For we are all philosophers at heart, in that we enjoy speculating about those realms into which science has so far made no entry.

Jeans makes much of the division of philosophers into two camps—the rationalists and the empiricists. The former of these believe that the highest truth resides within the mind and must be apprehended by reason, while the latter hold truth exists outside the mind and is to be discovered only by observation and experiment. Now the scientific method begins with observation and experiment, wherefore we would naturally expect to find the scientist among the empiricists. But it is well known that the exact opposite is the case. The greatest rationalists, Descartes, Spinoza, Leibnitz, and Kant were all of them men of science, two of them of the very first rank. On the other hand, the four greatest empiricists, Bacon, Locke Berkeley, and Hume, were men whose scientific training was negligible.

The author explains this anomaly as due to the difference between the British and Continental temperaments. The four rationalists are all continentals, and share the continental love of abstract ideas; the empiricists are all British and characterized by a love of practical investigation. But this theory is not altogether convincing. The four rationalists come from French, Spanish, Saxon, and Prussian ancestry, and it is difficult to imagine much unity of temperament in a group of such diverse origins. Further, the difference between rationalism and empiricism is largely one of degree, the empiricists admitting intuition and the rationalists restricting *a priori* apprehension to "higher" truth. Thus the contrast between the two schools appears more imaginary than real. And scientific method consists not only of the acquisition of knowledge but also its classification and the drawing of inferences from classified knowledge—an essentially rationalistic procedure. Perhaps a large element in this addiction of scientists to rationalism lies in the fact that scientists take up philosophy as a mental relaxation and find that rationalism offers greater facilities for this.

The final chapter is devoted to a discussion of that problem which has intrigued philosophers from before the dawn of history—freedom of the will. Most writers have run aground in wrestling with this problem, because they have sought its solution in a greater knowledge of the nature of will, instead of in the nature of freedom. Probably not all readers will agree with the author's conclusion, but undoubtedly many will, and certainly all will be refreshed and stimulated who read this book.

MICRURGICAL AND GERM-FREE TECHNIQUES: *Their Application to Experimental Biology and Medicine. A Symposium.*

Edited by James A. Reyniers. Charles C Thomas, Springfield, Illinois. $5.00. 8¾ x 5½; xiv + 274; 1943.

This volume, edited and prefaced by James A. Reyniers, contains the papers read at a symposium held at Notre Dame University, November, 1939.

The first section, on micrurgical methods, contains three papers: The design of micrurgical machines for use in bacteriology, by James A. Reyniers and Philip C. Trexler; Micrurgical application of surface chemistry to the study of living cells, by M. J. Kopac; and, Micrurgy and botany with special reference to phytopathology, by E. M. Hildebrand.

The second section, on germ-free methods, is made up of eight papers. Beginning with an introduction to the general problem of isolation and elimination of contamination by James A. Reyniers a chapter follows by the same author, in collaboration with Philip C. Trexler, on the germ-free technique and its application to rearing animals free from contamination.

The use of the mammalian fetus as an experimental animal in bacteriology is discussed by Oram C. Woolpart and U. Paul Hudson. In a chapter on the germ-free cultures of certain invertebrates, R. W. Glaser describes the techniques for growing germ-free protozoans, insects, and nematodes which lend themselves to a variety of interesting and important biological problems. Philip R. White discusses the germ-free tissue and organ cultures of plants and points out their value in physiological and pathological studies.

The last three chapters present what might be called a practical application of the more basic problem of isolation of a unit in that they deal with the problem of control of cross infection both air-borne and contact. James A. Reyniers discusses the use of mechanical barriers in preventing cross infection among hospitalized intact populations; I. Rosenstein and E. Kammerling have a paper on air conditioning, ultraviolet light and mechanical barriers as factors in the prevention of air-borne cross infections in nurseries. In the final chapter William F. Wells presents some data on the prevention of the spread of infection through ultraviolet barriers.

The papers as a whole contain a good bit of information that could be useful to workers in the field of biology.

FORWARD WITH SCIENCE.

By Rogers D. Rusk. Alfred A. Knopf, New York. $3.50. 8¾ x 5⅝; xi + 312. 1943.

This is a popular book written by a college teacher of physics who has attempted to make the recent develop-

ments in the physical sciences understandable and meaningful to the average intelligent layman. The writer believes that the achievements of science cannot remain only for the cloistered few if the scientific and technical level of our nation is to continue to rise. As a whole the author has been wise enough to sacrifice technical details for breadth of treatment and wideness of scope. Some of the numerous "almost unbelievable triumphs" of modern physical science which are discussed are: Important newly discovered particles such as the positron, neutron, and mesotron in addition to the electron and proton which a generation age were thought to be final; the amazing electron microscope with its magnifications ranging around 30,000; x-rays and the new million-volt machines for deep treatments of cancer, etc.; the cyclotron and the production of artificially radio-active substances from which come significant advances in physiology and medicine; the epochal experiment of splitting uranium; cosmic rays; the theory of relativity, etc. In his treatment of the various modern achievements the author has attempted to analyze their significance to human beings, their applications in war and their potentialities in times of peace.

The text is illustrated rather appropriately with photographs of the various machines mentioned together with their inventors, many of whom are Nobel prize winners.

ARE WARS INEVITABLE? *Smithsonian Institution War Background Studies Number Twelve (Publication 3730).* *By John R. Swanton. Smithsonian Institution, Washington, D. C.* Free. 9⅛ x 6⅛; iii + 36; 1943 (paper).

This essay divides itself naturally into two parts. The first deals with the biological aspects of war, and reads like a greatly condensed version of the corresponding part of Quincy Wright's *A Study of War* recently reviewed in these columns. Both writers conclude that war is a cultural and not a biological acquisition of the human species since it is not known to occur among sub-human beings.

The second part deals with the rise and fall of empires within historic times. It is strongly suggestive of *Coercion of States in Federal Unions*, published by the Pacifist Research Bureau, and it reaches the same conclusion, that war is not inevitable and that the "time when all wars shall cease" though painfully remote is yet surely coming. This conclusion is significant, since the bibliographies of these two works have but few references in common.

It is a healthy sign, and something of a surprise as well, that a nation that gives official recognition to war as an instrument of national policy should permit the publication during war time, by an agency of its government, of such a document as this, for it is essentially anti-war propaganda. Yet it is the twelfth in a series of such studies. He who reads it is likely to want the other eleven as well.

CARNEGIE INSTITUTION OF WASHINGTON YEAR BOOK NO. 41, JULY 1, 1941–JUNE 30, 1942, *with Administrative Reports through December 18, 1942.*

Carnegie Institution of Washington, Washington, D. C. 10 x 6¾; xxxii + 309; 1942 (paper).

As always, the *Yearbook of the Carnegie Institution of Washington* makes interesting reading. After Pearl Harbor, the Trustees

adopted a resolution, in accordance with which the Institution is meeting all requests from the government for scientific aid as fully as its facilities and resources will permit. It was recognized that this policy would inevitably interrupt most of the normal program of the Institution.

. . . To the extent of our ability and resources, and to the full effort of our personnel as it becomes determined how they can best serve, the Institution is committed to the service of the nation at war.

Thirty-four staff members are on leave and are taking part in war work, 145 others are giving full time to war research in the Institution's own laboratories or are devoting part time in various capacities to service for the government, while 28 members of the scientific staff are either members, technical aides, or consultants of sections of the National Defense Research Committee.

There has been a considerable drop in the income of the Institution. It is estimated that there will be a probable income for 1943 of $1,175,000. Comparing this figure with the income of $1,695,900 for 1936, it will be seen that probably some reduction in the activities of the Institution will be necessary.

FUN WITH YOUR MICROSCOPE. *By Raymond F. Yates. D. Appleton-Century Company, New York.* $2.00. 7⅞ x 5; ix + 150; 1943.

The past decade has witnessed an unprecedented increase in interest in the amateur scientist, and in the contributions he can make to the body of scientific knowledge through the pursuit of his hobby. This interest has manifested itself in the appearance of a number of fine hand-books, laboratory guides, and field manuals for use in instructing, guiding and encouraging the amateur along many lines of scientific endeavor.

Fun with Your Microscope is certainly one of the finest that has yet appeared on the subject of the structure, care, use, and application of the microscope to the problems of the amateur scientific enthusiast. The author's viewpoint as an amateur scientist, and his

broad experience in editing and publishing various scientific works, have been combined in the present treatise to produce a clear and invigorating insight into the wide possibilities of the microscope and related micro-equipment in the hands of the non-professional worker. The discussions cover not only the use, care, and construction of equipment for the home laboratory, but the accepted procedures and techniques for collecting, preparing and studying plant and animal specimens. Numerous graphic and photographic illustrations are used to further clarify the textual material. An index is provided.

MEDICAL JURISPRUDENCE AND TOXICOLOGY. *Seventh Edition.*

By John Glaister. Williams & Wilkins Company, Baltimore. $8.00. 8½ x 5½; viii + 671; 1942.

This is the (almost entirely rewritten) seventh edition of a book which since 1902 has rightly enjoyed great popularity. Its main chapters deal with the legal basis of the medical profession, medical evidence in court, post mortem technique, technique of identification, signs of death, asphyxia, death from lightning, burning, starvation, etc., medico-legal aspects of wounds, blood stain examination, medico-legal aspects of the sexual function, and lunacy. The rest of the book is devoted to toxicology, including war gas and air raid casualties. The disadvantage of the book of the Glasgow professor is, of course, that it refers only to English and Scottish law. The American reader will have to look up these details, e.g. in Peterson, Haynes and Webster's Handbook. This relatively small disadvantage of Glaister's book —after all the techniques of legal medicine are the same everywhere—are largely balanced by its exemplary literary presentation, its numerous excellent illustrations, its right proportioning of legal medicine and toxicology (⅔ legal medicine, ⅓ toxicology), qualities which make it superior to most textbooks in the field.

JOSEPH GRINNELL'S PHILOSOPHY OF NATURE. *Selected Writings of a Western Naturalist. Published in Commemoration of the Seventy-fifth Anniversary of the Founding of the University of California.*

University of California, Berkeley. $2.00. 9¼ x 6; xv + 237; 1943.

This commemorative volume is a collection of essays selected by Alden H. Miller from the writings of Dr. Joseph Grinnell on various phases of vertebrate zoology. All of them had previously appeared in various scientific periodicals.

Unfortunately the reproduction is confined to the text—the illustrations and maps from the originals being omitted, to the serious detriment of the value of the present work.

The editor, in his preface, states that if Grinnell had lived long enough to prepare this work himself it would have been a much better book. The reviewer concurs in this opinion.

INTERNATIONAL AGREEMENTS ON CONSERVATION OF MARINE RESOURCES *with special reference to the North Pacific.*

By Jozo Tomasevich. Food Research Institute, Stanford University, California. $3.00. 9 x 6; xi + 297; 1943.

This is a treatise on one phase of international cooperation in which the legal and political aspects are stressed. Despite the fact that it is published by the Food Research Institute the greater part of it deals with the protection of the Arctic fur seal. Among other matters discussed are the halibut and salmon fisheries and the whaling industry.

SOVIET SCIENCE.

By J. G. Crowther. Penguin Books, Harmondsworth and New York. 25 cents. 7⅛ x 4⅛; 191; 1936 (paper).

This is an abbreviated reprinting of an older work. Although it consists largely of an account of the present (prior to 1936) status of scientific activity in the Soviet Union the preface seems to indicate that the author's main objective is to give credit to Marx for the work done by Engels.

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